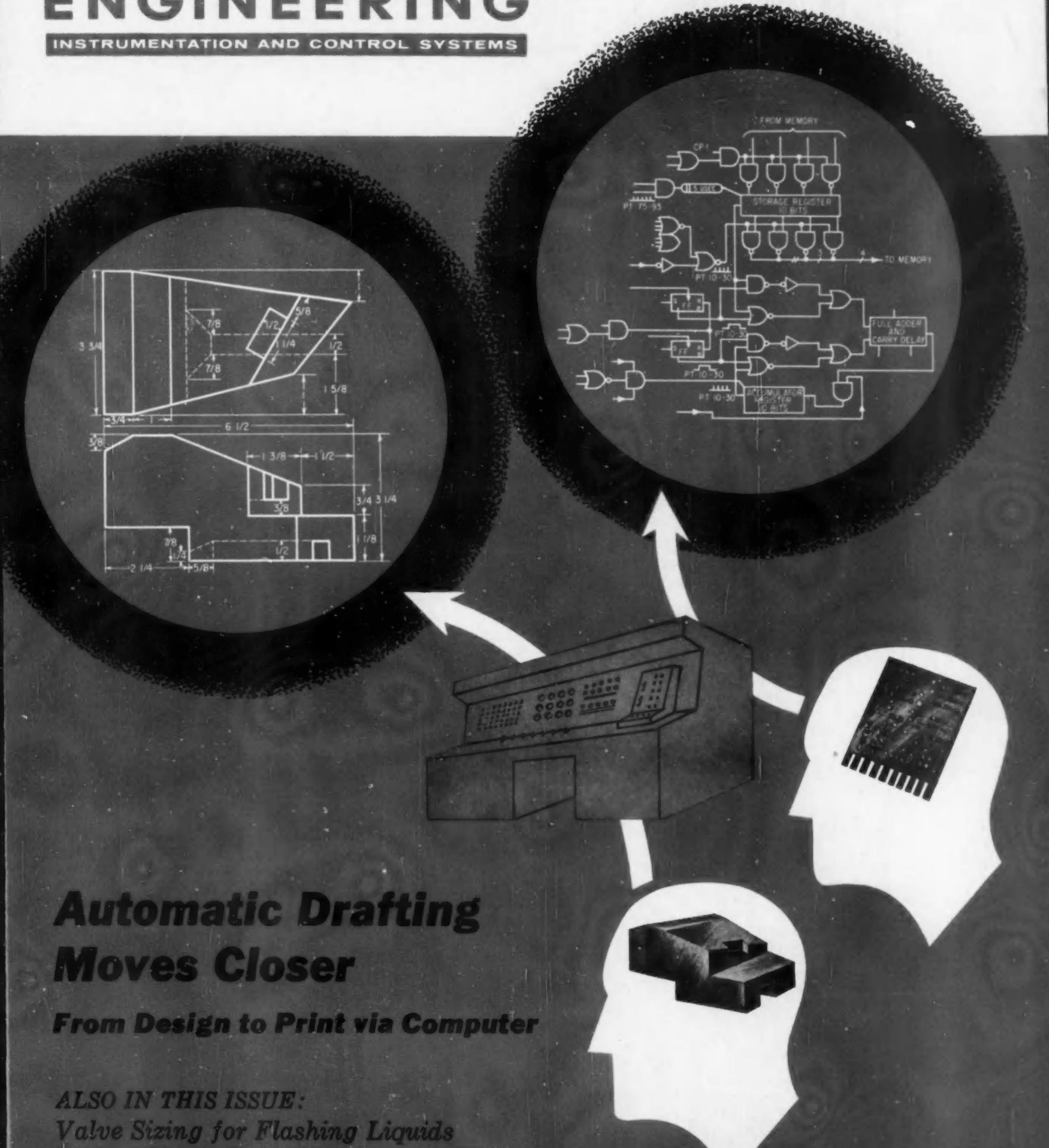
Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

75 Cents

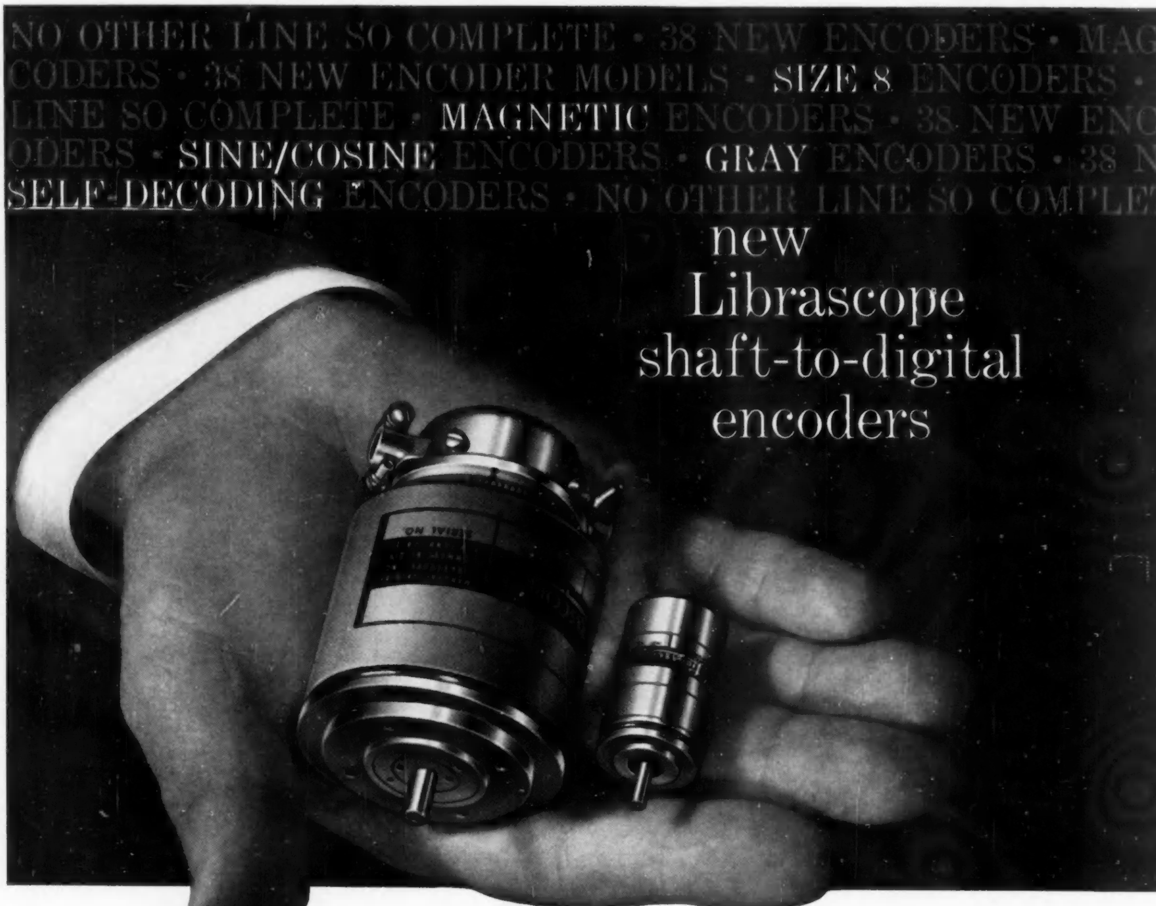
FEBRUARY 1961



Automatic Drafting Moves Closer

From Design to Print via Computer

ALSO IN THIS ISSUE:
Valve Sizing for Flashing Liquids
Two vs Three-Gyro Platforms
Opinions on Fire-Resistant Fluids



Librascope Shaft-to-Digital Encoders are highly accurate, reliable, shock-resistant, and versatile... ready to serve in a variety of applications including missiles, aircraft, machine control, computers, Doppler navigation and data processing. Accuracy that counts is the by-word of a Librascope Encoder... backed by the superior technology and reputation of one of the world's largest producers of *Computers that Pace Man's Expanding Mind.*

new noncontact magnetic encoder

MODEL NO. 807

FEATURES:

Long life, high reliability, high speed, natural binary V-Scan readout.

SPECIFICATIONS:

Output Code: natural binary
Resolution: (per input shaft turn) 128 counts
Full Scale Capacity: 7 bits*
Speed: operating from 0 to 10,000 rpm
Life Expectancy: 20,000 hours at 4,000 rpm; 4 x 10^9 revolutions
Starting Torque: 0.1 in-oz. max.
Diameter: 2"
Length: 1 13/16"
Weight: 5 ounces

*ALSO AVAILABLE IN 13, 17, AND 19 BIT CAPACITIES.

new subminiature size 8 encoder

MODEL NOS. 787 & 793

FEATURES:

Low torque, low inertia, long life, high reliability, withstands severe environments.

SPECIFICATIONS:

Output Code: natural binary
Resolution: (per input shaft turn) 128 counts
Full Scale Capacity: 7 bits, 13 bits
Speed: operating 200 rpm, slew 600 rpm
Life Expectancy: 2 x 10^6 revolutions at 200 rpm
Starting Torque: 0.5 oz-in. maximum
Diameter: .750"
Weight: 3 ounces

other popular Librascope encoders

Code	Model no.	Full scale capacity	Resolution per input shaft turn
Binary	773	13 bits	128 counts
	0-773	oil-filled unit for increased life	
Binary	710	10 bits	1024 counts
Binary	707 (707D*)	7 bits	128 "
	713 (713D*)	13 bits	128 "
	717 (717D*)	17 bits	128 "
	719 (719D*)	19 bits	128 "
	0-713	oil-filled unit for increased life	
Self-Decoding Binary	740	10 bits	1024 counts
B/C/D	723 (723D*)	2,000 counts	200 "
	724 (724D*)	20,000 "	200 "
	733 (733D*)	3,600 "	200 "
	734 (734D*)	36,000 "	200 "
	735	360,000 "	200 "
Sine/Cosine	757-S**	4 quadrants per turn	7 bits per quadrant + limit 1
	758 758-S**	4 quadrants per turn	8 bits per quadrant + limit 1
Gray	708	8 bits	256 counts

*Contain isolation diodes for multiplexing

**Servo driven, hermetically sealed

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CIRCLE 203 ON READER SERVICE CARD

Control ENGINEERING

FEBRUARY 1961

VOL. 8 NO. 2

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

Continued on next page

IDEAS AT WORK

WHAT'S NEW IN THE CONTROL FIELD

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Model 737A shown with Model 732A Converter Plug-In

→ Measure frequency dc to 220 mc
→ Measure period to 0.1 microsecond
→ Measure time interval 0.1 microsecond to 10^7 seconds
→ Count dc to 10 mc

CMC, first with solid state reliability, announces the transistorized Model 737A frequency-period meter.

Here, combined in one compact package weighing a scant 53 pounds, are the functions of a high speed counter, frequency meter, and period meter. Sensibly priced at $2400, the Model 737A mates an all solid state counter with a plug-in vacuum tube heterodyne converter.

Only 14" high, 17" wide, and 13" deep, CMC's new Model 737A requires a mere 125 watts of power which in itself reduces operating temperatures and contributes to long trouble-free life. And except for the vacuum tubes, the new unit is unconditionally guaranteed for two years.

THREE PLUG-INS AVAILABLE
1. 10 mc to 100 mc frequency converter; 2. 100 mc to 220 mc frequency converter; 3. Solid state 0.1 microsecond to 10^7 second time interval section.

Converter plug-ins $250 each. Time interval plug-in $300.

FEATURES AND ADVANTAGES ✱ *Decade count down time base, frequency divider circuits never need adjustment.* ✱ *Automatic decimal point.* ✱ *Nixie readout available as standard option.* ✱ *Stability, 2 parts in 10^7 standard, 5 parts in 10^8 special.* ✱ *Accuracy, ±1 count ± oscillator stability.* ✱ *Sensitivity, 0.25 v rms.* ✱ *Standardize against WWV.* ✱ *Remote programming without special regard to cable length, type of cable, or impedance matching.* ✱ *Printer output to drive digital recording equipment, punches, inline readout and other data handling gear, $80 extra.*

NEW TECHNICAL BULLETIN TELLS ALL

Your nearby CMC engineering representative will be happy to provide you with full technical, sales, and delivery information and arrange a demonstration at your convenience. For a free copy of our new technical bulletin, please address Dept. 21.

CMC 9 8 7 6 5 4 3 2 1 0

Computer Measurements Co.
A Division of Pacific Industries
12970 Bradley Avenue, Sylmar, California
Phone: EMpire 7-2161

CIRCLE 5 ON READER SERVICE CARD

Control ENGINEERING

FEBRUARY 1961 VOL. 8 NO. 2

Published for engineers and technical management men responsible for the design, application, and test of automatic control systems

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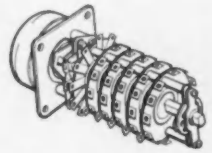
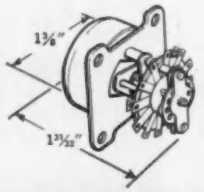
Ledex Rotary Selector Switch

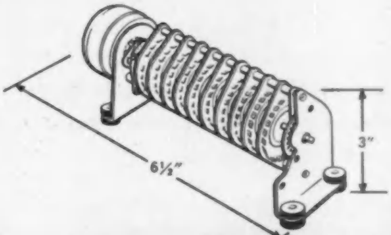
BASIC INFORMATION



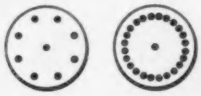
Functions as a power operated remote control circuit selector or stepping switch.



Smallest switch is size 26 with 1 to 4 switch wafers.



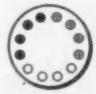
Largest standard switch is size 55 with 1 to 10 switch wafers, foot, flange or panel mounting.



8 position 24 position

Switch wafers available with 8, 10, 12, 18, 20 or 24 positions.

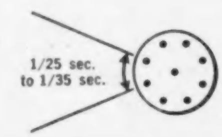
1 circuit, 12 positions



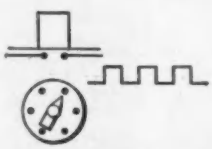
3 circuits, 4 positions each

Circuitry of wafers is flexible. For example 12 position wafer can be one circuit with 12 positions or 3 circuits with 4 positions each.

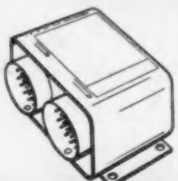
Will self-step to any pre-selected position.



Self-stepping speed is 25 to 35 steps per second depending on number of positions.



Pushbutton, manual rotary switch, or pulse controlled.



Hermetically sealed switches meet extreme environmental conditions.

The Ledex Rotary Selector Switch is a compact, highly efficient power-operated circuit selector or stepping switch, designed for remote control. Nearly unlimited design combinations permit great variety of applications for stepping, counting, adding, subtracting, programming and sequencing. Many stock models on hand for immediate shipment. Hermetically sealed models also available.

Power source is the Ledex Rotary Solenoid. This unit gives highest-torque-to-size rotary motion. Applications for Rotary Solenoids include actuation of valves, vanes, shafts, and other mechanical loads.

Also Ledex Syncramental Stepping Motors for accurate, reliable shaft indexing.

Write for literature, mentioning application, to Ledex, Inc., Dayton 2, Ohio; Marsland Engineering, Ltd., Kitchener, Ont.; NSF Ltd., 31 Alfred Place, London, Eng.; NSF GmbH, Nurnberg, Germany.

LEDEX

CIRCLE 7 ON READER SERVICE CARD

SHOPTALK

Special report on transistor switching

Just as in 1956, when many companies were pressing to put on the market static magnetic devices packaged for industrial switching, now some of these same companies and others besides are beginning to sell transistorized switching modules and systems to satisfy the increasing demand for reasonably priced, reliable industrial static switching devices. Next month's issue will feature a special report on industrial industrial transistor switches. Basic operation, available equipment, and typical applications are only a few of the areas that will be covered. Look for it!

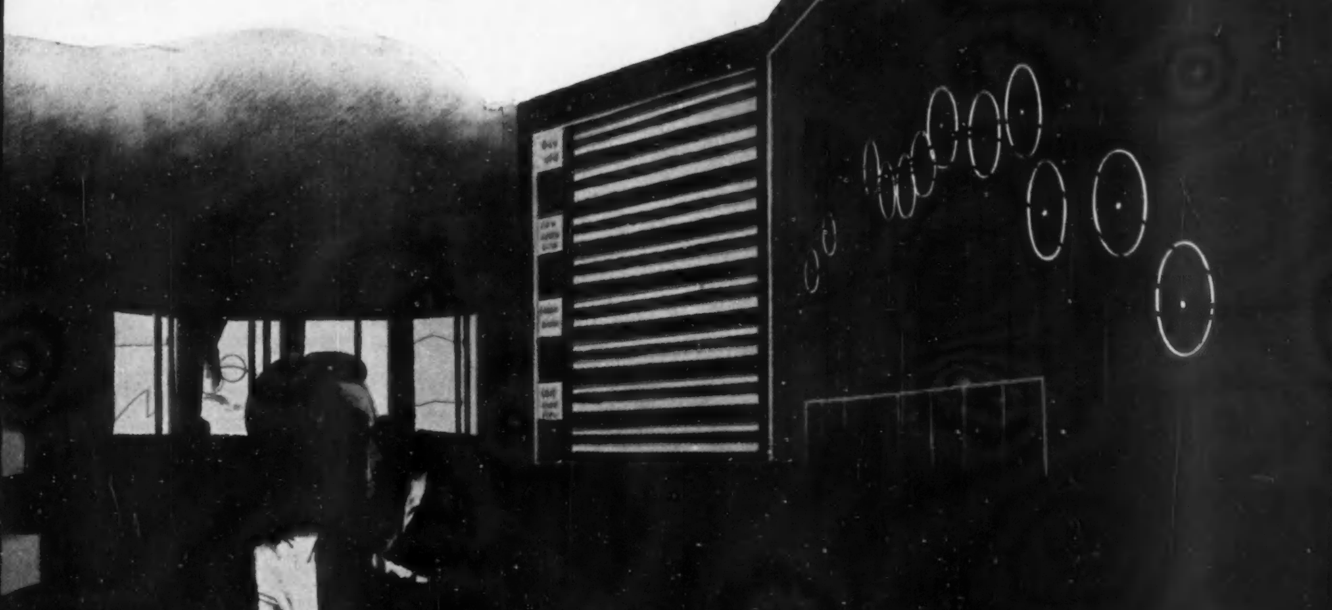
What do you think of fire-resistant fluids?

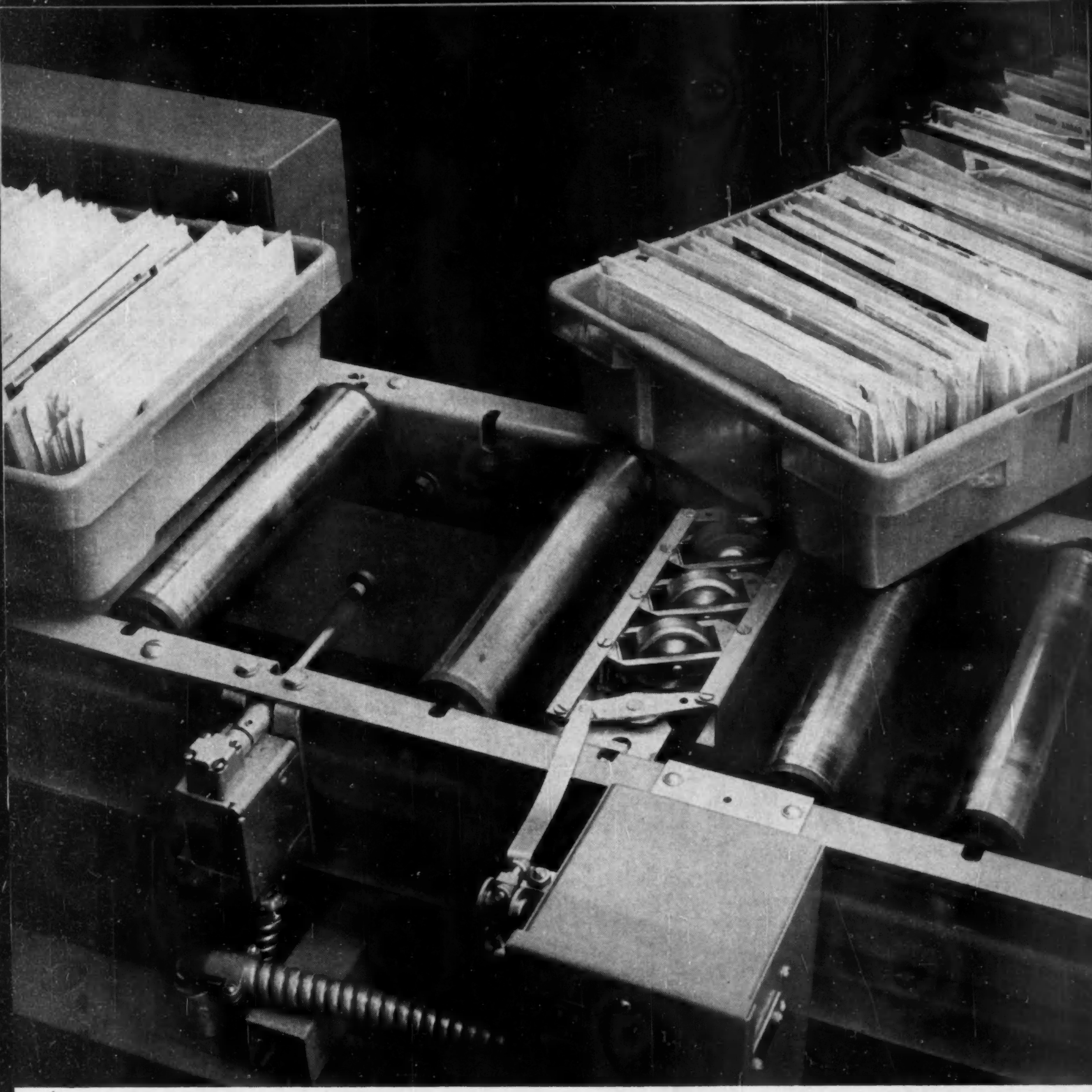
If you haven't had experience with these controversial fluids—or even if you have—don't miss reading "What Industry Thinks of Fire-Resistant Fluids," page 116. The survey was put together by Assistant Editor Livers and McGraw-Hill News personnel from personal interviews of engineers and insurance underwriters. It's a well rounded cross-section.

One tidbit from Bruce Cross of Midwest News Bureau that arrived too late to be included in the story points up the subject. A Chicago manufacturer used non-fire-safe fluids for many years without accident. One day a flexible hose on a hot-heading machine ruptured, hydraulic fluid sprayed over the machine, contacted hot metal and ignited. The fire spread almost instantly to the hydraulic accumulator about 50 ft away and a witness described the result "as one big ball of flame." Total loss: well over $1 million. Since then they have switched completely to fire-resistant fluids. No insurance company has since refused them coverage.

He put the electronics into computers

Robert F. Shaw, now vice president of Digitronics Corp., started designing electronic computers early. His background sounds like the computer family tree. After an AB in physics from Princeton and graduate work in EE at Moore School of Electrical Engineering he participated in the logical design, circuit design, and test of major portions of the ENIAC, first all-electronic digital computer, in 1943—18 years ago. Then in order came the EDVAC, IAS computer, Binac, Univac, Ordifiac, Elecom 100, Elecom 120, and Elecom 125. In 1957, when Underwood Corp. decided to get out of the computer business, Bob joined others in the Computer Division management and started Digitronics. Lately he has been interested in digital data transmission equipment, a topic he covers thoroughly in the article on page 127.

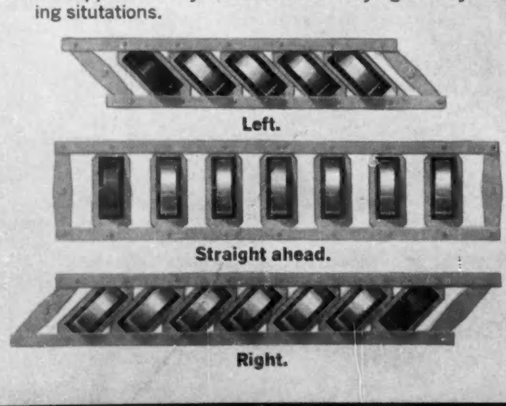


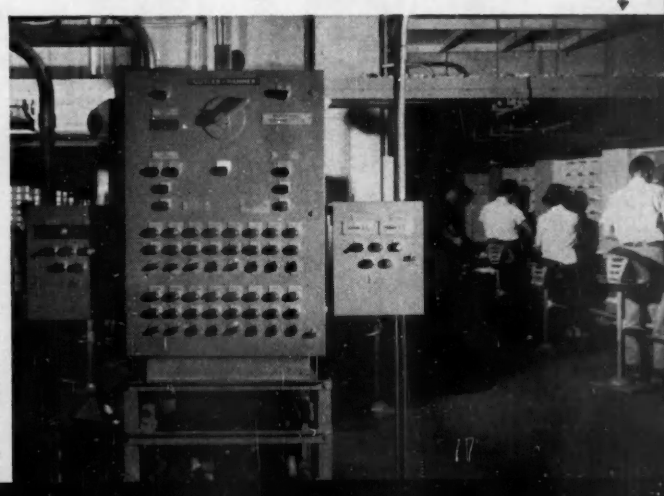


On command from the card reader (left above) the skate wheel assembly turns, sending the tray where it is supposed to go.

Main control panel shows status of mail tray flow on conveyors. The inspector can tell at a glance which sorting station needs mail.

The Cutler-Hammer skate wheel assemblies can be supplied in any width to meet varying conveying situtations.





FEEDBACK

How is it done in Russia?

To the Editor—

On page 27 of the August issue there are two references to analog computer usage by the Russians. We would appreciate additional information from Derek Barlow (author of story) on the application of analog computers to control of electric power generation and distribution.

E. W. Sheridan
Link Div. of GPI
Binghamton, N. Y.

The analog computer controls least-cost supply of power to a distribution network. Each generating station is represented by a function generator, whose input voltage analogs incremental cost and output current analogs the power supplied. All the function generator output currents pass through a passive network for simulation of transmission network losses. A meter adds outputs to show the total load.

Operation is based upon the criterion that at the optimum setting the incremental costs of all stations must be identical. The criterion is met by manually adjusting one voltage fed to all function generators, until the total load meter indicates that the total load is met. Meters at individual function generator outputs then indicate the optimum load for each station; a teletype transmits this information to the actual station.

The computer is used for both instantaneous load and for prediction of 24-hour load. Derek Barlow.

Wants industrial static switching

To the Editor—

We ask your advice on a problem: could you supply the names of any manufacturers of static switching systems that are used to switch resistance thermometers and strain gage networks? If there are any articles on this particular problem, we would be most interested to know of them.

K. A. Middleton
Philips Electrical Inds. Pty. Ltd.
Sydney, Australia

Pages 10 and 11, August 1960 issue list several manufacturers of computer-type transistorized logic modules that may be used for your purpose. (Proper division of Epsco is Epsco Components.) In addition, the Square D Co. of Milwaukee, Wis., manufactures an industrial line of transistorized NOR logic modules with the trade name Norpac.

If you would prefer static switching devices using magnetic amplifier circuitry, the following companies have been supplying these devices packaged for industrial application for some years; Industry Control Dept., General Electric Co., Roanoke, Va.; General Purpose Control Dept., General Electric Co., Bloomington, Ill.; Westinghouse Electric Co., Pittsburgh, Pa.; and Magnetics, Inc., Butler, Pa. Ed.

Profits from report; wants reprints.

To the Editor—

I am privileged to be the instructor in our Air Reserve Officer Training Course for research and development officers. We are presently getting together resource materials to be used in the course in the coming year. Having read with interest and personal profit the special report on "System Characteristics of Modern Guidance Techniques" which appeared in your August issue, I would like to inquire as to the possibility of securing a dozen reprints to be used by the students in our course.

L. E. Kanous
Capt., USAFR
Madison Heights, Mich.

We are glad to offer reprints of the special report; see page 165 for order blank. Ed.

Has progress and product.

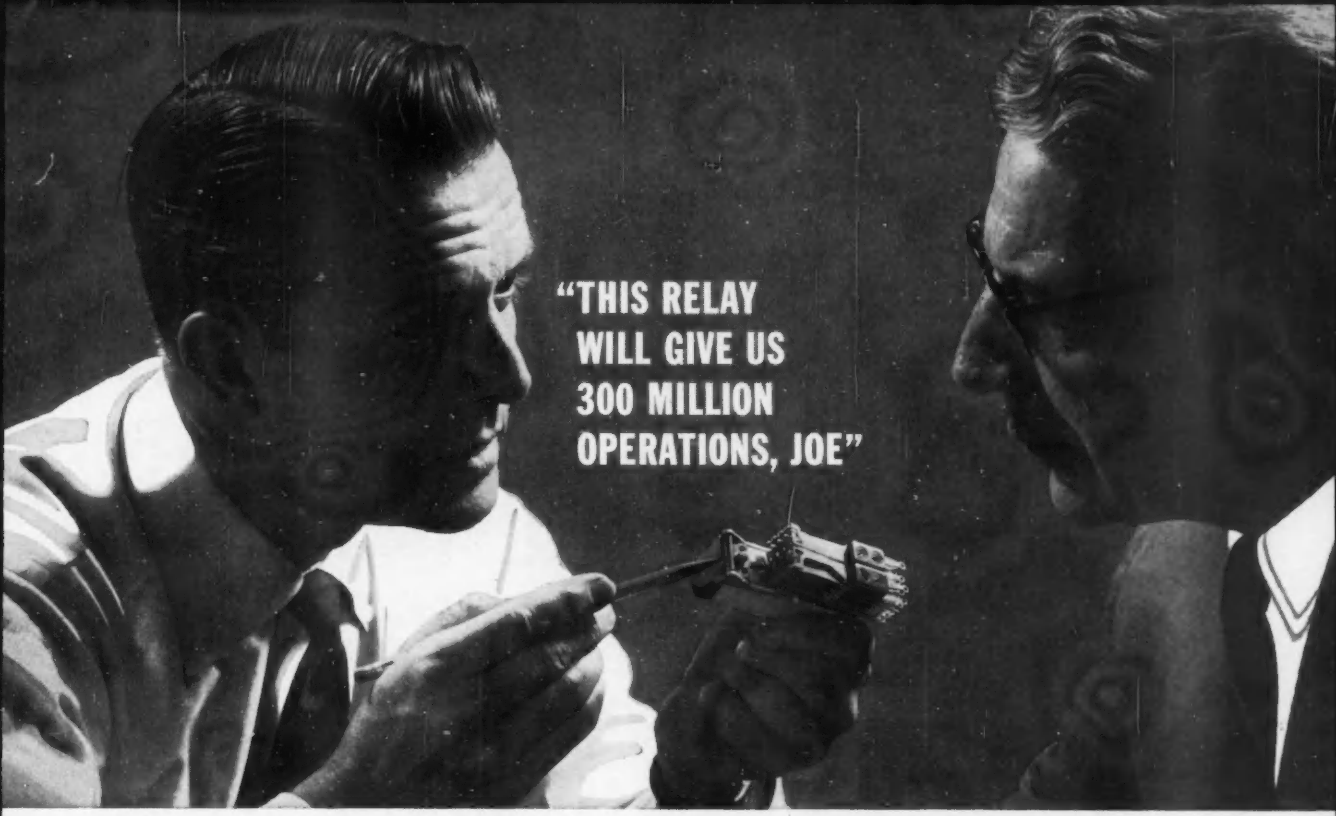
To the Editor—

We read with great interest the story "Smog Instrumentation: Apathy Numbs Progress", by D. Winston and M. Murphy in the September issue of Control Engineering (pp. 30–35).

The authors state (p. 35) that " . . . specialists would like to see a field instrument capable of measuring low concentrations of hydrocarbons right at the point of emission." In connection with this statement, I would like to mention that such an instrument already exists. It is our Model 213 hydrocarbon detector, built especially for the analysis of low concentrations of total hydrocarbons directly at the point of emission.

Leslie S. Ettre
Product Specialist, Chromatography
The Perkin-Elmer Corp.
Norwalk, Conn.

The Perkin-Elmer and Beckman instruments were exhibited at the ISA



HERE'S WHY P&B TELEPHONE TYPE RELAYS GIVE YOU

reliable performance over long life

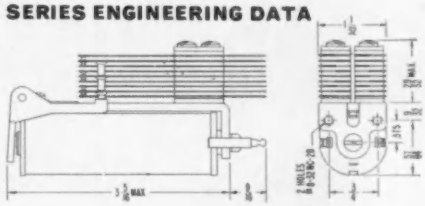
BS SERIES TELEPHONE TYPE

Measure the thickness of the BS series armature arm. You will find the cross section area is greater than ordinary relays of this type. Here is the kind of quality that spells dependability.

Observe that the stainless steel hinge pin runs the full width (not just half) of the armature, providing optimum bearing surface. This pin, operating in a stainless steel sleeve, shows only minimal wear during nearly a *third of a billion operations.*

Best of all, P&B quality costs no more. A whole new plant is being devoted to the production of high performance telephone type relays. Your nearest P&B sales engineer will be happy to discuss your relay problems. Call him today.

BS SERIES ENGINEERING DATA

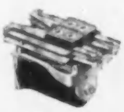


GENERAL:
- **Breakdown Voltage:** 1000 volts rms 60 cy. min. between all elements.
- **Ambient Temperature:** −55° to +85° C. +125° C available on special order.
- **Weight:** 9 to 16 ozs.
- **Terminals:** Pierced solder lugs; Coil: One #16 AWG wire; Contacts: Two #18 AWG wires
- **Enclosures:** Dust covered or sealed

CONTACTS:
- **Arrangements:** DC—up to 28 springs; AC—up to 24 springs
- **Material:** 1/16" dia. twin palladium. Up to 1/4" dia. single silver. Other materials on special order.
- **Load:** 4 amps at 115 volts, 60 cycle resistive
- **Pressure:** 15 grams minimum

COILS:
- **Resistance:** 100,000 ohms maximum. Current: 10 amps maximum
- **Power:** DC—50 Milliwatts per movable arm. Greater sensitivity on special order. AC—17.9 volt-amps.
- **Duty:** Continuous
- **Treatment:** Centrifugal impregnation
- **Voltages:** DC—up to 300 volts with series resistor. AC—up to 250 volts, 60 cy.

MOUNTING: Two #8-32 tapped holes 3/4" o.c. Other mountings on special order.



GS SERIES—Excellent sensitivity: 50 mw per movable arm minimum (DC). For applications requiring many switching elements in small space.

LS SERIES—Medium coil relay with short springs and light weight armature for fast action, reliability and long life.

TS SERIES—Short coil relay is available in AC and DC versions. Long life construction. Can be supplied (DC) with up to 20 springs (10 per stack).

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY, PRINCETON, INDIANA

IN CANADA: POTTER & BRUMFIELD CANADA LTD., GUELPH, ONTARIO

CIRCLE 15 ON READER SERVICE CARD

FEEDBACK

shows in San Francisco (May 1960) and New York (Sept. 1960) and at the exhibit during the Annual Conference of the Air Pollution Control Association in Cincinnati (May 1960). Ed.

Think in eights, work in twos.

To the Editor—

Mr. Ed Bukstein's letter to the editor (Sept. '60, p. 18) treated the subject of Binary to Decimal Conversion very ably. However, he failed to explain that engineers using binary computers think in the octal number system rather than the binary system. Binary numbers are easily converted to octal by partitioning the numbers in groups of three (i.e., 1,-010, 001, 100 binary) then converting directly to octal.

EXAMPLE	Binary		Octal
	1	=	1
	010	=	2
	001	=	1
	100	=	4

or 1,010,001,100 binary = 1214 octal usually written $(1,010,001,100)_2 = (1214)_8$.

A simple technique for conversion from octal to decimal follows:

Assume an octal number $N = A_n r^n \ldots A_2 r^2 + A_1 r^1 + A_0 r^0$

Where $r = (10)_8$ and $A_n = 0, 1, 2 \ldots 7$ and $n = 10 - 8 = 2$

Then using decimal arithmetic:

$$N_0 - 2A_n r^{n-1} = N_1 = B_n r^n \ldots B_1 r^1 + B_0 r^0$$
$$N_1 - 2\,B_m r^{n-2} = N_2$$
$$N_n - 2\,B_m r^0 = N \text{ decimal}$$

EXAMPLE

$$\begin{array}{rr} & 1{,}214 \text{ octal} \\ 1 \times 2 \times 10^2 = & -200 \\ \hline & 10{,}14 \\ 10 \times 2 \times 10^1 = & -200 \\ \hline & 81{,}4 \\ 81 \times 2 \times 10^0 = & -162 \\ \hline & 652 \text{ decimal} \end{array}$$

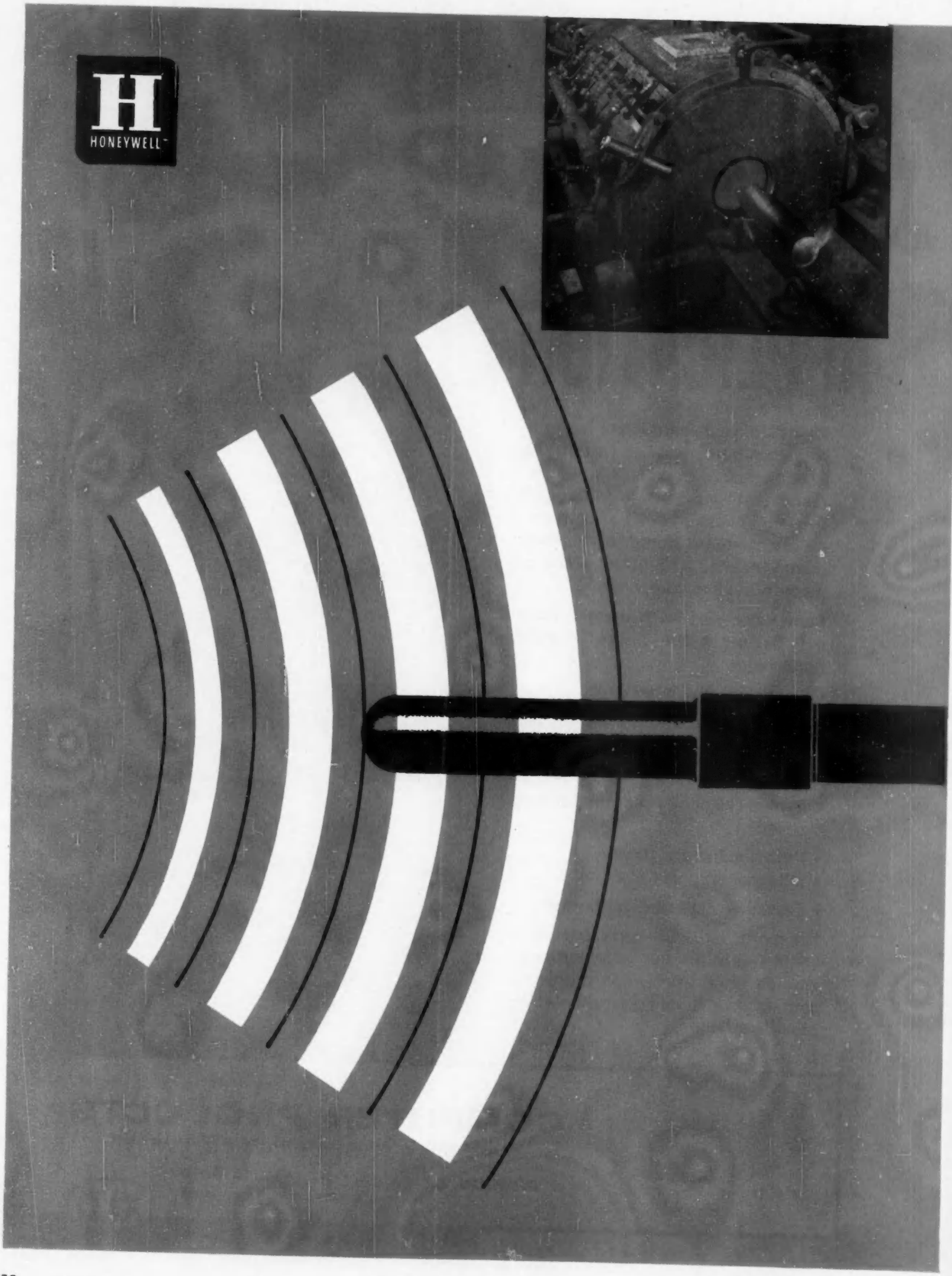
This technique can be proved mathematically by collecting terms in the following relationship:

$$A_n r^n + \ldots A_2 r^2 + A_1 r^1 + A_0 r^0 = B_m S^m + \ldots + B_2 S^2 + B_1 S^1 - B_0 S^0$$

Where $r = 10 - 2$ (octal number) and $S = 10$ (decimal number)

I suggest anyone interested in number systems refer to the November 1955 issue of Control Engineering, pages 82-89, for one of the best descriptions of "Orderly Number Systems" I have found.

George Etsell
Pacific Power & Light Co.
Portland, Ore.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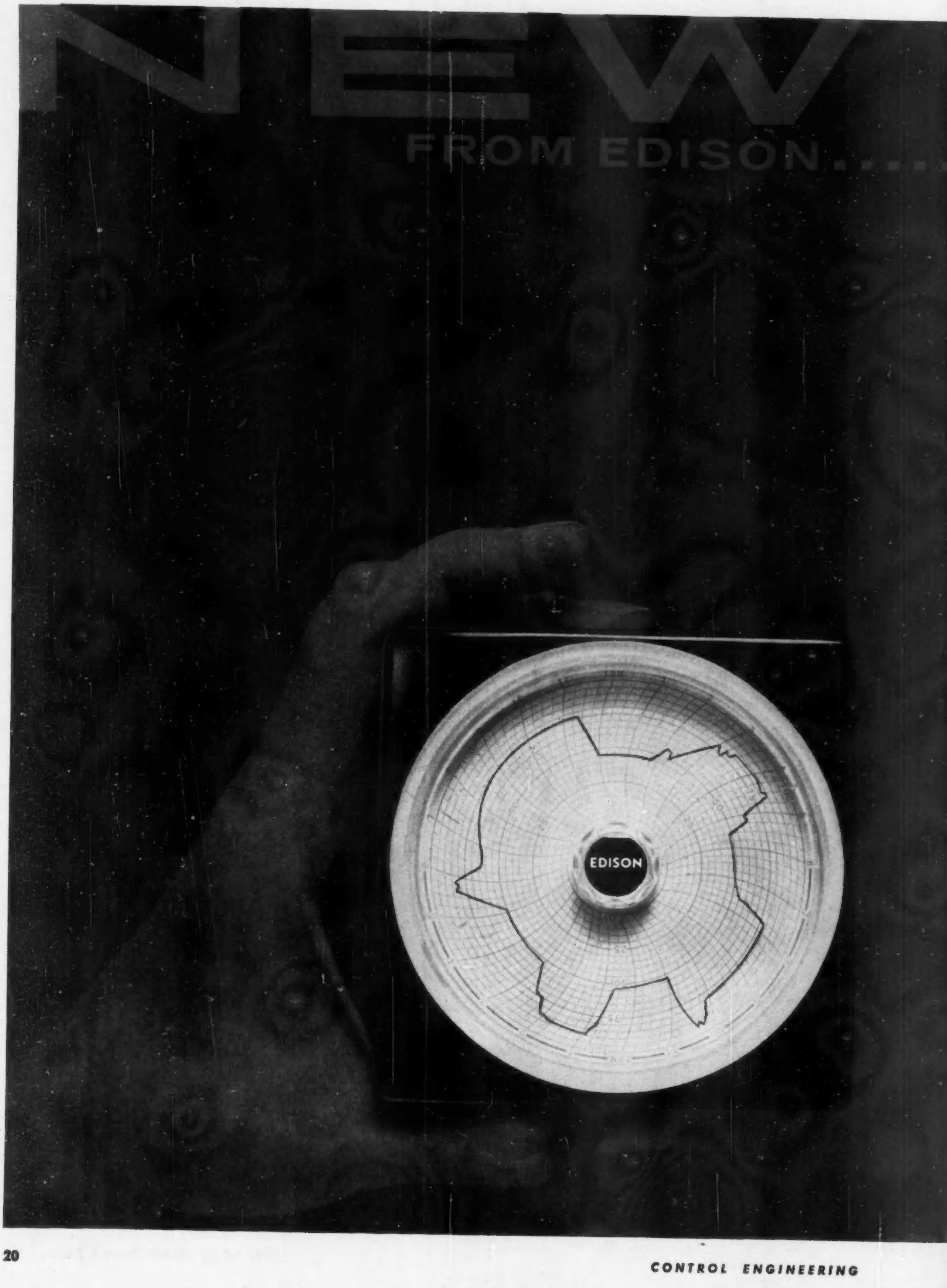
HONEYWELL


NEW
FROM EDISON.....
EDISON

....OMNICORDER

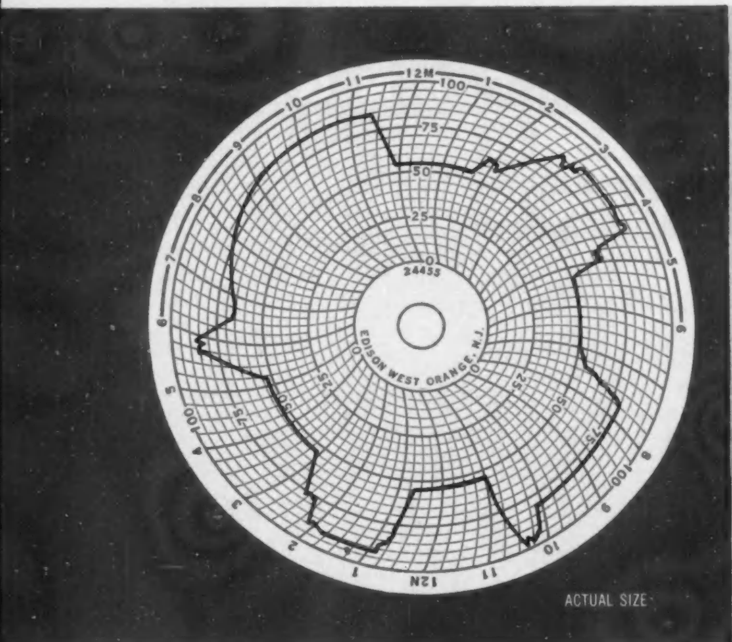
A PRECISE MINIATURE INKLESS RECORDER

■ INEXPENSIVE ■ REPLACES METERS OR INDICATORS ■ PANEL OR BULKHEAD MOUNTED
■ BUILT-IN VARIABLE CHART SPEED ■ JUST 3¾" X 3¾" X 3" ■ RECORDS ANY VARIABLE

Now you can take advantage of a new, economical means of recording any variable that can be converted to an electrical signal. Thanks to Omnicorder, you need no longer rely on meters or indicators, even where cost factors or space restrictions would ordinarily dictate the use of these instruments.

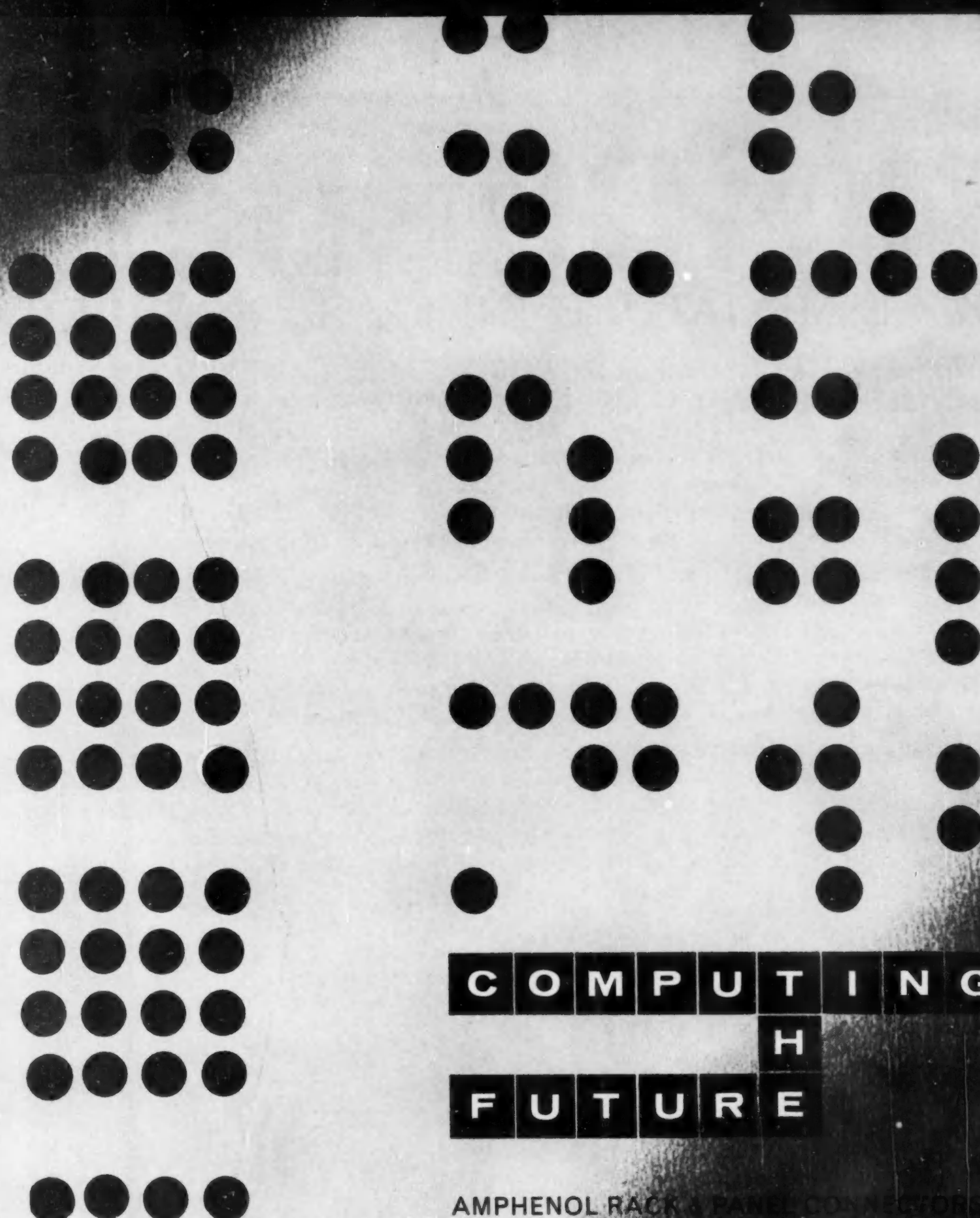
Measuring just 3¾" x 3¾" x 3", Edison's Omnicorder, a unique circular chart recorder, is so compact that nine units occupy just one square foot of space. Thoroughly legible, yet requiring no ink, pen or ribbon, Omnicorder is equipped with a simple three-speed chart adjustment. It provides a choice of these sequences: one hour, seven hours and thirty hours per revolution—or one day, seven days and thirty days per revolution.

Omnicorder's simple, inexpensive construction assures dependable operation and a long, maintenance-free life. Four types of meter movements are available to measure a wide range of AC and DC electrical quantities, ranging from thermocouple outputs to currents as high as 600 amperes with accessory current transformers. No amplification is ever required, even for signals as low as 10 microamps.



For complete information on this rugged, maintenance-free Omnicorder, write for Catalog 3057.

Thomas A. Edison Industries
INSTRUMENT DIVISION
38 LAKESIDE AVENUE, WEST ORANGE, N. J.



William A. Summers

made an idea work

Proposed control system for an automatic electric generating station: take a digital computer with extensive, flexible memory; add miniature electronic instruments, pressure gages, switches, recorders and controllers; install special equipment to display trend and other interpretative information on plant operation; and then connect these components into a reliable system to make all operating and safety decisions for the plant.

Such an advanced control system is now being installed in a power plant. But the initial concept, as laid out here, was formulated twelve years ago, before most of the hardware to carry it out was available. This radical approach was the brainchild of William A. Summers and J. B. Rice, two bold engineers at Ebasco, the engineering firm that specializes in power plant design. In 1949, toying with the utilities' perpetual problem—how to deliver power to the consumer reliably—they decided that a fully automatic generating plant was the answer. In the past twelve years, Bill Summers has helped bring the concept to fruition through a series of plant designs that have advanced the state of the art step by step. And today's modern installation, he proudly points out, is almost identical with that 1949 plan.

When he joined Ebasco in 1948, after graduating from Cooper Union in New York, Bill Summers brought to the engineering firm what was a new and unusual discipline for Ebasco. He was a chemical engineer, hired to join an embryo organization that was to specialize in the design of chemical plants. But for work, Summers found himself assigned to Ebasco's mechanical engineering department, working on electric generation stations.

Swayed by a background in electronics, gained during a two year war-time assignment at the Naval Research Laboratory, Summers found his interest in power plant design centering about control problems. During those freshman years, he pursued special studies in turbine, combustion, and safety control. Culminating his indoctrination in the power plant field, he wrote a 26 volume operating manual for a new generating station.

To develop his 1949 idea of an automatic generating station he discovered, he had to prove that utilities could benefit from less-than-ultimate control systems, thus selling his approach little by little. In 10 years he marched through the design of stations whose generating capacity would total over 5 million kw.

▶ In 1952, anticipatory load control—now a common feature—was introduced at Kansas City Power

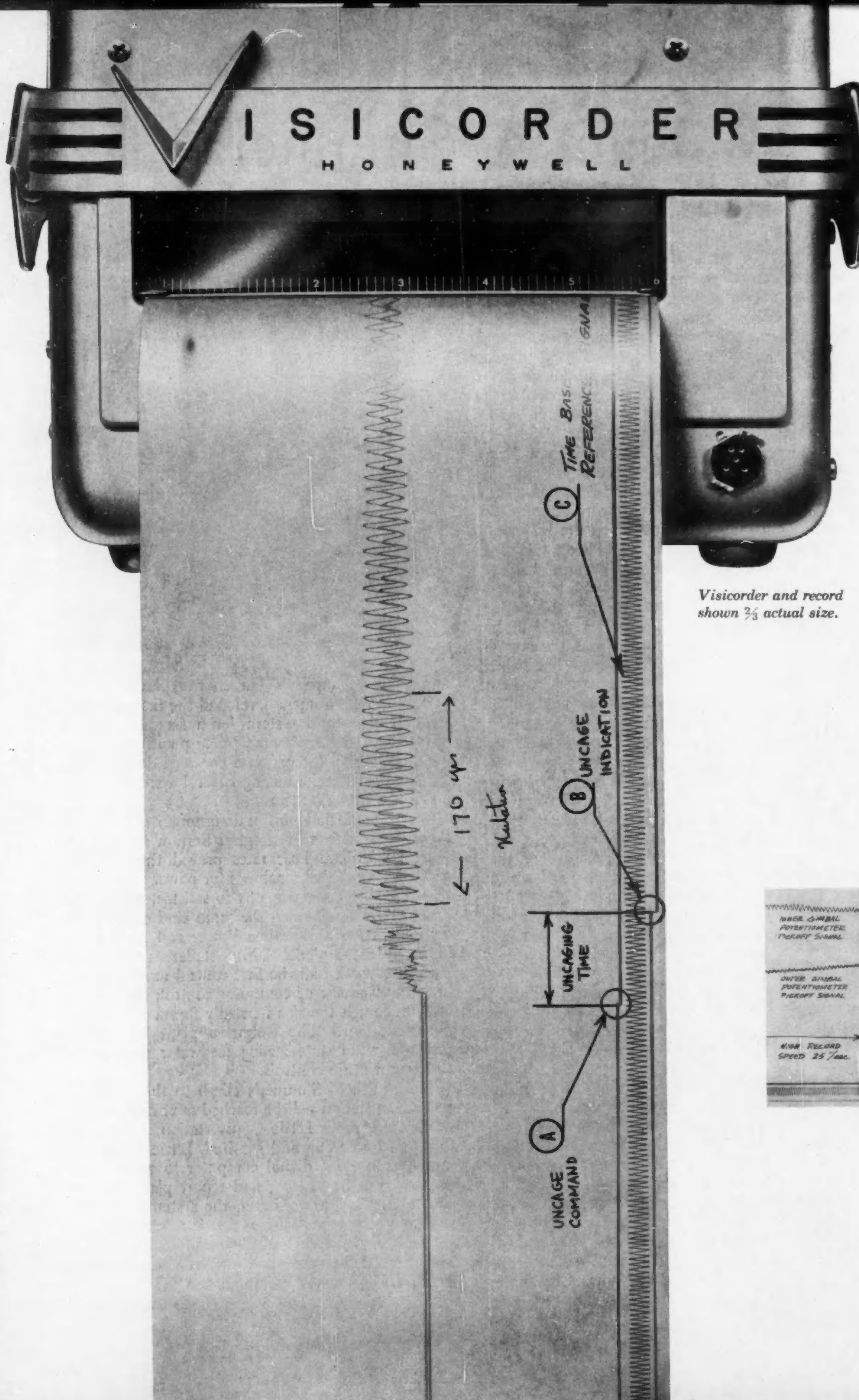
and Light Company's Hawthorne plant.

▶ By 1954, Summers developed the first integrated safety and control system for a six-unit coal-fired station at Electric Energy's Joppa plant.

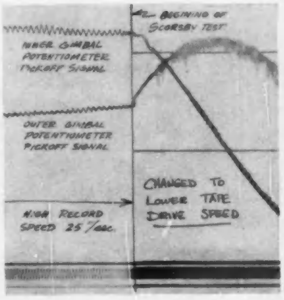
▶ In 1957, he integrated a complex decision-making system with the analog control system to make a steam plant easier to run.

▶ In 1958, installation of a computer at Louisiana Power and Light's Sterlington Station to log operating guides and heat rates proved the reliability of solid state digital machines for power plant operation. In fact operation was so satisfactory, in 1959 Summers recommended the same kind of computer for installation at Carolina Power and Light's new H. B. Robinson plant. This installation was a landmark because it had the first control room designed to take advantage of computer control; the room is just one-fourth the size normally found in coal-fired power stations. The Robinson plant has another first too: solid state analog feedwater combustion, and temperature controls.

The zenith of Summer's climb to the automatic generating station will be reached next month when Louisiana P & L's Little Gypsy station is scheduled to go on line. Oil- and gas-fired, Little Gypsy will initially rely on a digital computer to gather information, run the station, and report plant performance to the operator. Later, the system will supervise all analog control functions; if a malfunction is detected, it will switch automatically to digital control, running the generating unit by a comparison of direct and inferential measurements.

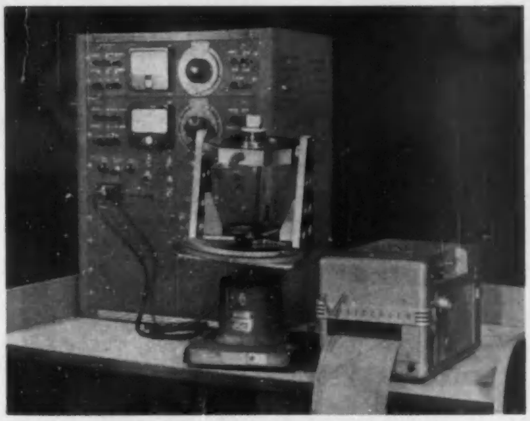


Visicorder and record shown ⅔ actual size.



How the Visicorder helps keep "spring" in a free gyro

by simultaneously recording several performance characteristics



In this simple bench set-up, the 906 Visicorder is at right. Between it and the control panel is the Scorsby table on which the gyro is mounted, ready for test.

How do you production-test a spring-wound miniature "free" gyro which has been designed for a limited number of firings without changing its characteristics due to excessive testing? Whether a gyro under actual conditions will reproduce test results depends to a large extent upon how many times it is "fired" before its short but important life begins. The multi-channel high-frequency Visicorder makes it possible for Whitaker Gyro Division of Telecomputing Corp. to test simultaneously all operating characteristics with only one firing of the gyro.

Five channels of a Honeywell 906 Series Visicorder are used in the test for *uncaging time* and *gimbal drift*.

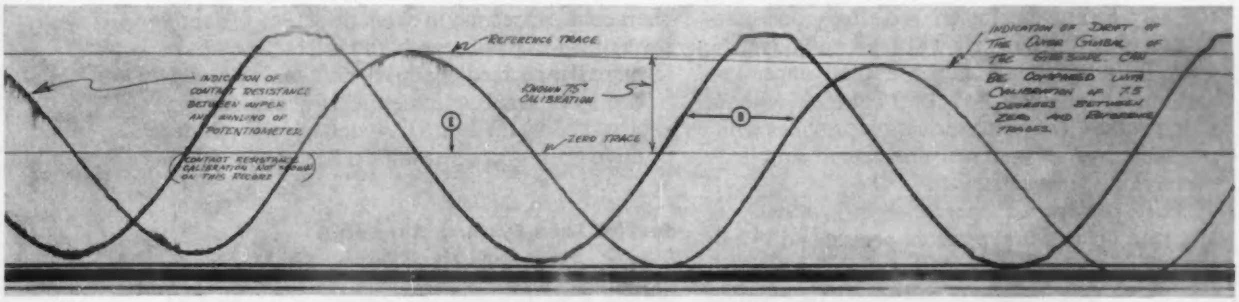
For the uncaging time study, a squib is fired to release the gyro's spring motor. One trace indicates squib firing (A). When the gyro attains correct speed (and uncaged condition) a switch closes to record another trace (B). Between these traces, a 400 cps trace is a convenient time reference (C).

The gyro is mounted on a Scorsby table set to deflect the unit 7½ degrees from the perpendicular about two axes. Potentiometers sensing the gyro's deflection are directly connected to galvos which measure the position of the gyro gimbals as the unit is rotated on the fixture. The potentiometer outputs trace individual sine waves on the record (D) which are easily compared to a zero trace (E) to indicate gimbal drift.

The records shown here in two parts are actually one continuous record. Immediately after the uncaging time test, the record drive was switched to lower speed *without* stopping the record. The resulting traces are easy to compare and gimbal drift is measured immediately.

Four different models of the Honeywell Visicorder oscillograph provide immediate readout of analog data from DC to 5,000 cps, with 8, 14, 24 and 36 channel capacity. Prices are as low as $1845 for a 6-channel system with grid lines and built-in timer (Model 1406). Call your Industrial Sales Office soon for a demonstration of how the world's most versatile oscillograph can save you time and money in data acquisition.

Ask, also, for your free copy of the 36-page Visicorder Applications Manual, an engineering guide packed with problem-solving suggestions.



The record at left was made at a speed of 25" per second. The record above is a continuation, after record speed was changed to 1" per second without interrupting the test sequence.

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Newsbreaks In Control

Industry Waits For Burroughs New Line

New York—Industry sources hear that the Burroughs Corp. will introduce two radical new lines of computers, the 3500 and 5000 series, sometime during the first quarter of 1961. What will make the computers different, say experts, is arithmetic speed made possible by thin film memories, faster than that in the IBM Stretch computer (the high speed machine built for the Atomic Energy Commission).

Another Utility Buys Computer Control

Boston—Boston Edison is the latest electric utility to include a computer in mechanization plans. The utility will install an Information Systems, Inc. general purpose digital machine in its Mystic station as part of a wider mechanization program at the station.

Electronic Trading Stamps

Dallas—Electronic data processing will replace trading stamps in a unique test about to start in Texas and Oklahoma. In this test, inaugurated by American Premium Systems, customers will receive a credit card like that issued by oil companies. When a purchase, is made, the credit card is imprinted onto a slip along with a number of points for the purchase. All the slips are transmitted to a central data processing system where they are read, totalized and stored automatically. When a customer's total reaches a certain number, the center sends the customer a certificate for those points.

New Mechanization Systems for Retailing

New York—New methods of mechanizing retail operations through electronic data processing continue to be introduced. At the National Retail Merchants Association meeting, in January, two new complete systems debut: one, offered by Farrington Mfg. Co., involves a simple sales slip imprinter, and an optical scanning machine to automatically read sales slips and convert them to computer format; another, made by International Telephone and Telegraph, puts a sales slip into a plastic jacket to which a piece of magnetic tape is attached containing information about the transaction.

West Coast Unions Buy Mechanization Pact

Los Angeles—An agreement that would spur mechanization of handling operations on West Coast piers has been approved by union forces. In an election last month, members of the International Longshoremen's and Warehousemen's Union voted for an agreement that would permit their employers, the Pacific Maritime Association, to introduce any labor saving equipment. In return, the employers group agreed to pay a guaranteed wage to the dock workers. Only the Los Angeles local voted against the pact.

Chemical Plant Puts Computer on Wheels

HOUSTON, TEXAS—
Shell Chemical Company has ordered a Packard Bell Computer PB 250 GP digital machine installed in a van so it can be moved from one unit to another. First application is to monitor the performance of processing operations at several different locations.

The mobile system will receive analog data from 60 sources, convert it to digital form for computation, and then record the output on magnetic tape. The system will also be programmed to energize alarms, make logical decisions, and log out performance on a typewriter or in punched tape. During field operation, the computer can be battery-powered when no ac source is readily available.

Ultraviolet Beam Carries Data

BALTIMORE—
Engineers at the Westinghouse Electric Corp. have built and demonstrated an experimental data communication system that transmits information over an ultraviolet carrier.

A standard television camera is the input device. Input information is fed to a cathode ray tube whose short persistence phosphors radiate ultraviolet. If the CRT bombardment is controlled, the ultraviolet emission is modulated.

An optical reflector focuses the light beam and sends it to the receiver, a photometer. The receiver converts the modulated light back to a television image.

Biggest advantage of the system appears to be a considerable saving of space and hardware since compact optical reflectors can beam the light to achieve antenna gains of several million; and the ultraviolet communications systems would be free from celestial and thermal noise.

Computer Vote Counter Clears Legal Hurdles

LOS ANGELES—
The special purpose computer developed to validate, tally, and store the votes cast in Los Angeles elections (CtE, Feb. '60, pp. 65-69) has faced a series of legal obstacles that make the technical problems already solved seem like child's play. The machine's first big chore was to have been the 1960 presidential elections, but the legal hurdles could not be solved in time.

Although the project started in 1956 as an idea in election officials' minds, it wasn't until 1957 that design really got under way. A California taxpayer's suit against voting machines delayed the work 14 months until a state court declared voting mechanization constitutional. Then Norden, the designer and builder of the equipment, ran into trouble on the paper handling problem.

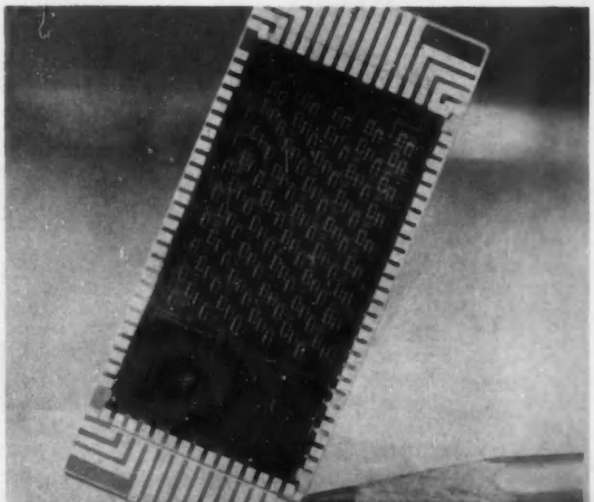
Finally, the tide started to turn. Last fall, the machine demonstrated to LA election officials that it could read and tally ballots as its specified speed—20 per sec. Then it was ready for state approval.

Last month Electrada Corp., a data processing company commissioned by the state of California to evaluate the prototype equipment, reported the machine's accuracy was 99.94 percent—well above that attained by a human vote counter. One flaw in the machine: it rejected two percent of the ballots as unreadable and those had to be tallied manually.

As a result of the report, the State Commission on Voting Machines, finally sanctioned the counters for use on January 12. Now, because of the closeness of the last presidential election in California, local officials are asking for faster delivery of the electronic counters.

Postage Stamp Memory

This cryogenic thin film memory plane, the size of a postage stamp, has been built by IBM's Federal Systems Div. Laboratory to perform computer memory operations not now possible with magnetic cores, magnetic tape, or drums. The plane is made up of 135 thin film cryogenic devices, built in a 19-layer sandwich. 120 of the cryotrons store 40 bits of information; 10 of them permit access to the stored bits of information; the remaining five are "in-line" and switch bits of information from one memory plane to another. Three cryotrons make up each memory cell, which combines storage with an elementary logic function. IBM has built an automatic system to turn out the memory planes in volume and reproduce them exactly.



Here's 0.1° Sensitivity at a Competitive Price!

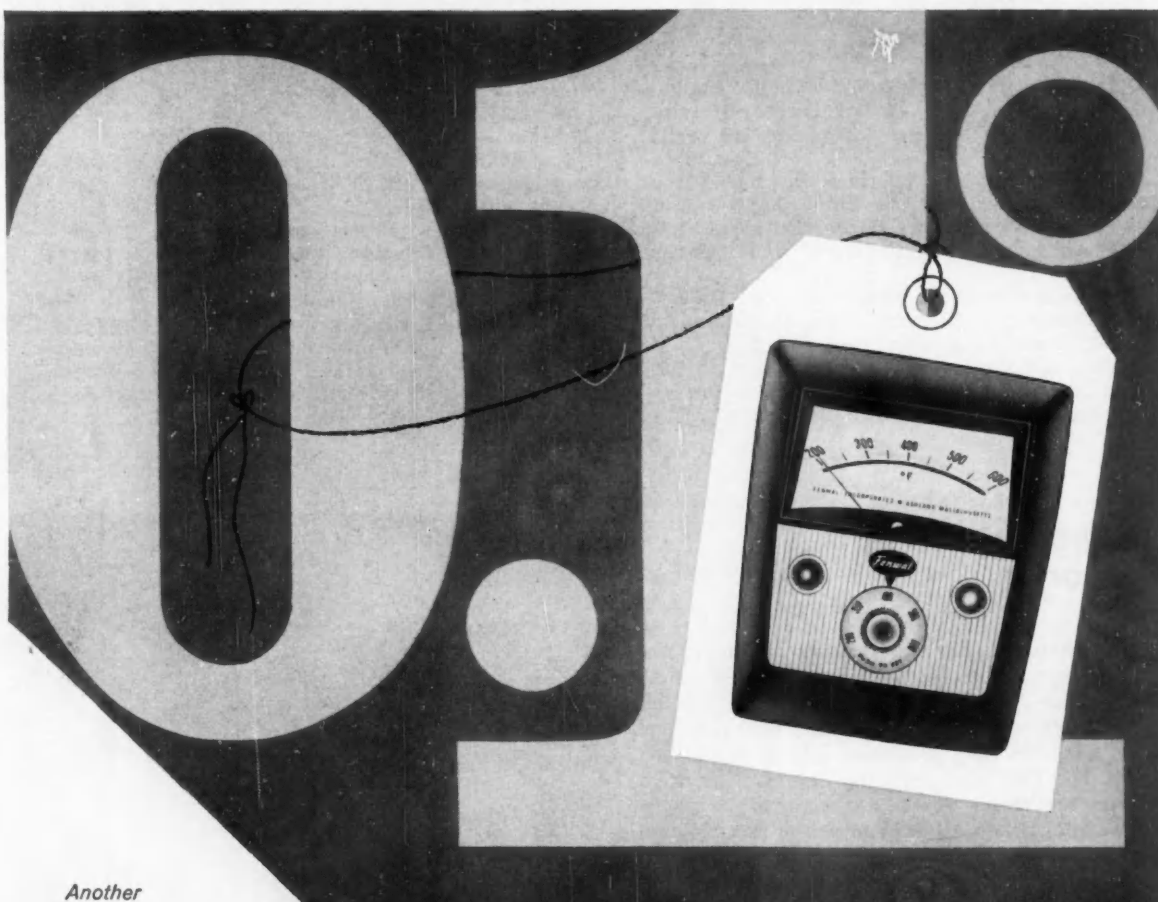
...Fenwal's New "561" Temperature Controller

The new "561" indicating controller responds to temperature changes of 0.1° or less! And is yours at a competitive price! These two features alone make it an instrument you should investigate...but there's more!

You can choose from five standard temperature ranges . . . within the span of −50 to 600°F. Furthermore, scales start and end within *your* ranges, permitting larger graduations, better legibility, easier read-out. And control and indication are separate but simultaneous. *Should your indication fail the "561" will continue to control with complete accuracy.*

This precise instrument gives unvarying performance. Its indication and control will not vary with fluctuations of input voltage nor changes in ambient temperature. It offers the option of either ON-OFF or proportional control . . . has 10 AMP/120 VAC relay capacity. Smartly styled to complement modern industrial machines and interiors, *the "561" offers you all these extras at a competitive price.*

A Fenwal engineer will be glad to supply information on the "561", or any other temperature control in Fenwal's broad line. Write Fenwal Incorporated, 292 Pleasant Street, Ashland, Massachusetts.



Another example of how

Fenwal CONTROLS TEMPERATURE . . . PRECISELY

Automatic Drafting Moves Closer

Data processing equipment modified for a manufacturing job bridges the gap between designer and finished print—without a draftsman. Charactron tube equipment produces drawings for parts to be made by numerical control. Industry asks: can the idea be extended?

SAN DIEGO—

Designers in the aircraft industry have a new degree of freedom because the parts they design can now be produced by numerically controlled machine tools. Numerical control has slashed hours—even days—from the production time for parts of complex geometry. But the time to prepare a working print for shopmen and inspectors remains the same, sometimes as long as weeks, and often increases as the designers take advantage of the flexibility of numerical control.

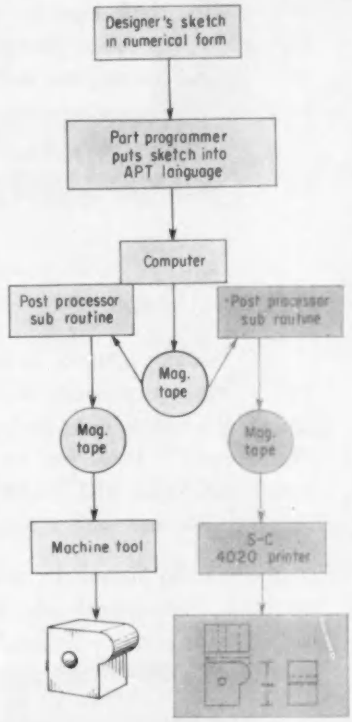
By modifying a piece of data processing output equipment, Stromberg Carlson Div. of General Dynamics has produced an automatic drafting machine that turns out a working print in less time than is required to make the magnetic tapes which control the programmed machine tool. And the drawing is made from the same input information. In fact, once the part has been designed and programmed for the machine tool, a working print like that on CtE's cover or below can be produced in less than a second. It represents a good example of finding new non-data processing applications for data processing gear.

This machine is the Stromberg Carlson 4020 Microfilm Recorder, which incorporates a Charactron tube and has been used as a high speed printer in computer centers. At the first installation, at the Naval Proving Grounds in Dahlgren, Va., where it was intended to print out firing tables, Stromberg-Carlson men envisioned the automatic drafting concept while watching NPG computermen draw experimental ship hulls using the SC printer after the designs had been computed on the NORC computer.

• **Numerical design**—The steps in the automatic drafting concept are shown in the block diagram. Once the designer has completed his conceptual design, he puts it into numerical form so that a part programmer can convert the sketch into the language of the Automatic Programming Tool System (APT), the system developed at MIT for the Air Force. With APT a programmer converts a parts configuration into algebraic form and puts it into computer format. The computer then calculates the tool cutting path and reproduces it on magnetic tape.

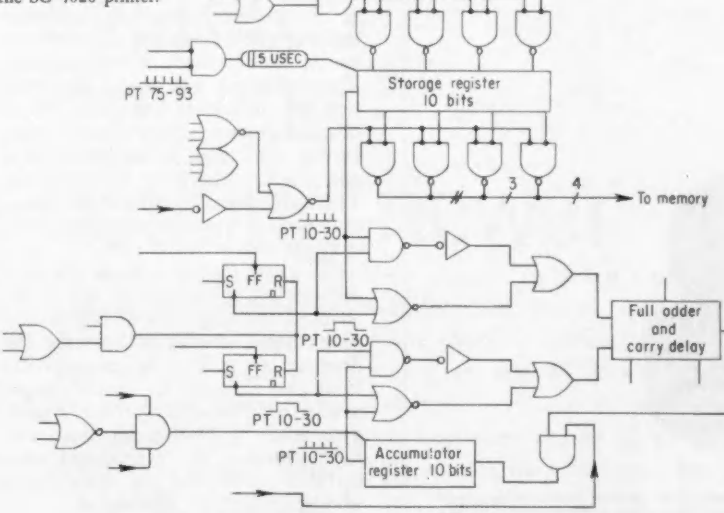
In normal manufacturing operations, this tape, which is in standard format, is then passed through a post processor, a computer subroutine that converts the general information on the tape into specific data on another magnetic tape for the particular control system on the machine. The second tape runs the machine tool.

To make a print with the automatic drafting system, the first computer-produced tape is also run through a different post processor that makes a second tape to program the SC-4020 high speed printer. All the information appears on a high resolution, high



From designer's sketch to working drawing with new automatic drafting system. Portion in color, showing steps in print production, can be compared to procedure to prepare control tapes for programmed machine tool.

Wiring diagram prepared by the SC 4020 printer.



WHAT'S NEW

intensity cathode ray tube which is photographed by a 35 mm camera. Standard prints can be made from the film record (which can be filed). The finished drawing contains not only an outline of the part but all other essential manufacturing data, such as dimensions, tolerances, and materials.

• **Obvious advantage**—The automatic drafting procedure has obvious advantages when working with numerical control. Those parts of the procedure that take the most time are creating the design and programming the part for the computer—two steps that have to be done in numerical control manufacture anyhow. Because the drawing is made automatically from the same input information as the machine tool tape, the print can be used to check the tapes for gross errors in part shape or dimension. Normally, the tape has to run on the machine tool and produce a part to check the tape's correctness. Finally the automatic process puts a print in the hands of inspectors before it starts turning out parts.

One question that has not been answered is whether this approach is economically feasible. It requires a piece of expensive equipment, the SC-4020 high speed printer. Cost about $250,000: renting for over $5,000 per month.

Automatic drafting this way appears to be easy to justify economically if the high speed printer is also used as a computer center output device. At Convair Astronautics, for example, where the first installation is to be made, Convair will use the SC-4020 to plot experimental trajectories of missiles as well as to make drawings.

• **Without numerical control?** — More intriguing to industry, however, is the broader aspect of automatic drafting when numerical control is not to be the method of manufacture. The technique will work: the question is economic feasibility. Most time-consuming portion would be converting the design to numerical form and programming it for the computer. There has been so little of this done that nobody wants to guess how long it might take or might cost.

To prove that the SC-4020 could produce wiring diagrams as well as mechanical drawings, Stromberg-Carlson programmed a computer to make the drawing on p. 31. Design engineers think that drawings for electrical apparatus already being designed by a computer—such as motors, synchros, and transformers—could be produced automatically. But the big question is whether it will be economical.

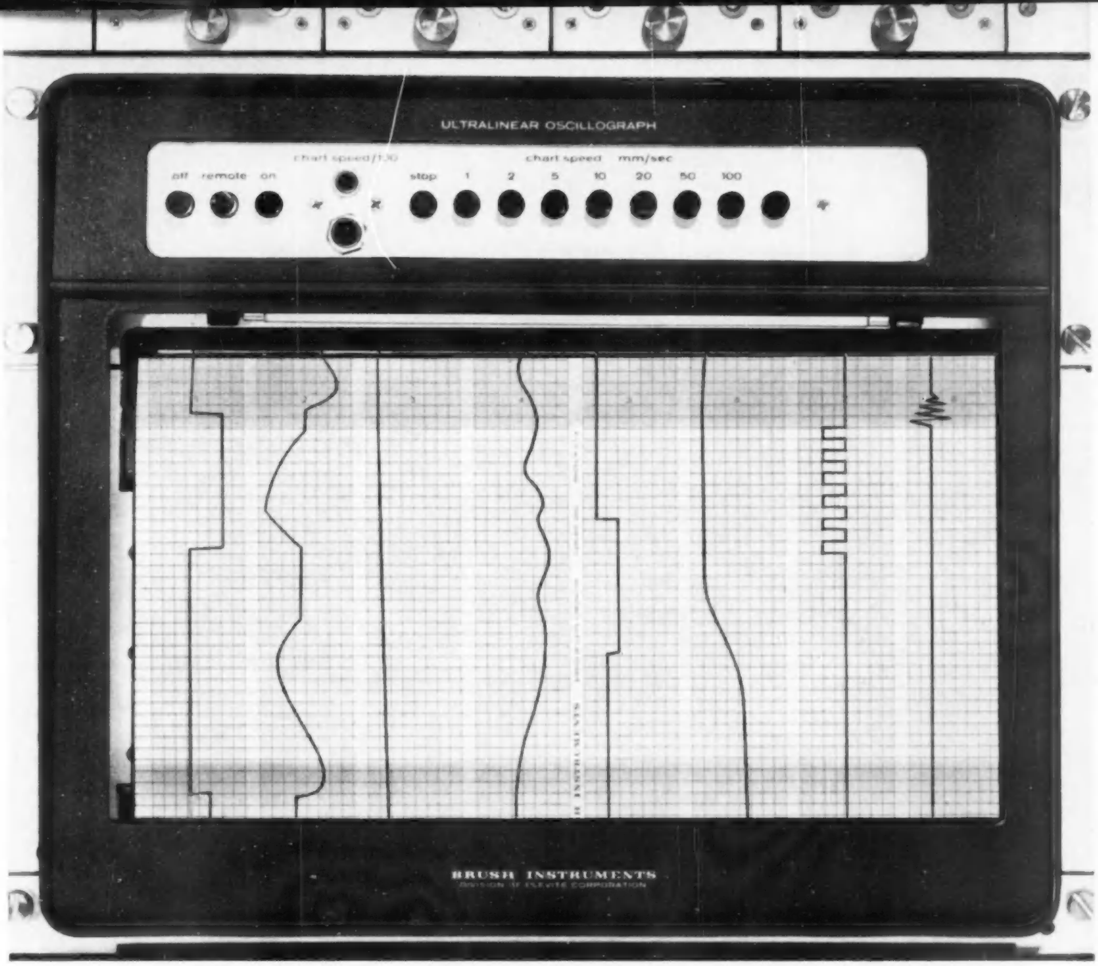

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chart speed/100
chart speed mm/sec
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Floating Input: Both sides of the input may be floated above or below ground. The floating input circuit provides more than 80 db rejection to 60-cps common-mode signals. A grounded input is also supplied.

Extended Range: A 10% extension is incorporated in each of the V-45's three ranges. Voltages up to 10.999 may be read on the 10-volt range; voltages up to 109.99 may be read on the 100-volt range; and voltages up to 1099.9 may be read on the 1000-volt range. Therefore, the operator need not constantly shift back and forth between ranges when reading close to the normal upper limit of a range.

Transistorized Logic and Drive Circuit: The V-45 DVM uses construction techniques representing the latest state-of-the-art, with all-transistorized circuitry driving reliable stepping switches.

Cubic manufactures a complete line of quality digital instruments, including a-c and d-c voltmeters, ohmmeters, ratiometers, scanners and printer controls. Write for literature to Dept. CT-101, Industrial Division, Cubic Corporation, San Diego 11, California.

SPECIFICATIONS

MODEL V-45 DIGITAL VOLTMETER

Input Impedance: 10 megohms at balance.

Ranges: Manually selected, 10% extended range
Low ±0.000 to ±10.999 vdc
Mid ±00.00 to ±109.99 vdc
High ±000.0 to ±1099.9 vdc

Sensitivity: 1 millivolt

Sensitivity Control: Continuously variable from 1 digit to standby lockout.

Power Input: 105-125 vac, 50-60 cps, 25 watts standby, 30 watts operating.

Dimensions: 19" wide, 5¼" high, 14" deep, rack or bench mounting with dust-proof switch and bridge section.

Average Balancing Time: Less than 2 sec.

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Communication Satellites:
New Problems in Control

Satellites with commercial significance are being readied. Control engineers are devising schemes to keep them in orbit and pinpoint where they are. Here is a rundown on the problems and projects under way.

WASHINGTON—Moving out of the realm of scientific curiosity, the space satellite is heading for its first commercial application: to relay information. Last month, as one of his last official acts, President Dwight D. Eisenhower approved a policy favoring private development of communication satellites. At least half a dozen companies—American Telephone and Telegraph (with its subsidiary Bell Telephone Laboratories and Western Electric Co.), General Electric, Motorola, Hughes Aircraft Co., Radio Corporation of America, and Philco Corp.—are actively working toward commercial space communication systems. They have discovered that making a space satellite part of a communication system introduces two new control problems: how to keep the satellite in a predetermined orbit and how to track the satellite with required precision.

In early satellite launching, the big control problem was putting the satellite into a prescribed orbit. Refinements in radio-guidance systems and inertial systems have basically solved this problem so that scientists feel they can put a satellite into the orbit they predict. But maintaining a satellite in the same orbit month after month is another story.

• **Active or Passive**—A satellite to relay data, messages, TV pictures or facsimile can be passive—the electrical signal is merely bounced off it—or active—it receives, stores, and on command, retransmits information. Last year, U. S. government agencies successfully launched both passive and active communication satellites to prove the feasibility of both.

Echo 1, launched by the National Aeronautics and Space Administration in August, is a 100-ft diameter balloon that serves as a passive relay station bouncing radio signals off its reflecting surfaces. The Army's Courier IB, launched in October, is active, can handle up to 100 channels of data.

Whether a communication satellite is active or passive, its tremendous cost demands that its life be extended as long as possible. A T & T, for example, figures it would have to spend $180 million on a satellite system for international telephony. The life is determined by how long any equipment aboard will function and how long the satellite can stay in orbit. Most experts feel that three to five years is the minimum life to make a satellite economical.

Satellite orbits are affected by both atmospheric and cosmic drag (the slowing effect of air and cosmic particles) by ion sweep up, meteorite colli-

Communication Satellite Plans

Date	Name	Type	Sponsor	Remarks
1961	One Echo	Passive	NASA	
	One Courier	Active	U.S. Army	Exchanges information at rate of 136,000 words per min.
1962	One Echo	Passive	NASA	
	One Advent	Active	U.S. Army	Synchronous orbit at altitude of 22,300 miles.
1963	One passive system	Passive	NASA	20 balloons in two orbits 1,500 miles high.
	One Advent system	Active	U.S. Army	A number of hovering satellites.
1964	Two multiple systems	Passive	NASA	Using more than one satellite.
No Firm Date or Firm Plans	Chaff Belt	Passive	U.S. Air Force	Belt of aluminum needles to reflect communication signals.
	Repeater Satellite	Active	Hughes Aircraft	Repeater stations that hover in a synchronous orbit.
	Telephone Satellite	Passive	NASA and AT&T	Balloon to rebound international telephone messages.
	Satellite chain	Passive	U.S. Air Force	Six balloons 6,000 miles apart connected by string.

COMMUNICATION SATELLITES (CONT.):

sion, pressure of sunlight, and some forces scientists still haven't completely identified. Most of the control hardware that looks reasonable for solving the problem is too heavy at present. To date there are no proven systems for keeping a satellite in orbit, but several different kinds of proposals have been made.

• **Bouncing ball**—One suggestion is to install a thrust device that will continuously exert on the satellite a force equal and opposite to those acting to pull the satellite out of orbit. Another proposal suggests a device that will supply thrust only when the satellite has slowed down to a given speed (the diameter or orbit shrinks as the speed decreases). The new thrust would be just sufficient to return the satellite to its original orbit.

A disadvantage of the continuous thrust system is that the life of the satellite then becomes dependent on how much propellant can be carried. The orbiting body needs a stabilization system to keep it oriented so thrust is applied in the right direction.

If the thrust is applied only as needed, more control hardware is required. For one thing two separate thrusts are needed for each maneuver. The first to bring the spatial relay to the proper altitude; the second to stabilize the satellite into its orbit.

Such a system is complicated because every maneuver requires different thrust. The weight of the satellite changes as propellant is used up. Thus, each successive thrust would have to be slightly reduced. A special purpose computer in the control loop could figure the necessary thrust; or engines of various thrust levels might be installed; or a combination of the two could be used. But all these ideas increase the amount of nonproductive weight the satellite must carry.

• **Spin the ball**—Other engineers feel that spin stabilization is a better answer to orbit maintenance. The theory is that a spinning satellite does not drop out of orbit as rapidly as a nonspinning one. Over a period of weeks, however, even a spinning satellite will drop back toward the earth.

At least two systems have been proposed to keep a satellite spinning. One, that was incorporated in the Tiros meteorological satellite series, has several small rockets that can be fired on command to supply the push to keep the ball spinning.

A more intriguing system, not yet tried experimentally, would put an electric coil around the satellite. Electric current applied at intervals would keep the satellite spinning. On paper, this electrical spinning system appears to have the best potential for keeping satellites at the right orbit.

Until the U. S. has larger rocket engines available for boosters, however, weight will remain a critical factor. Control systems will have to be minimized to keep poundage small.

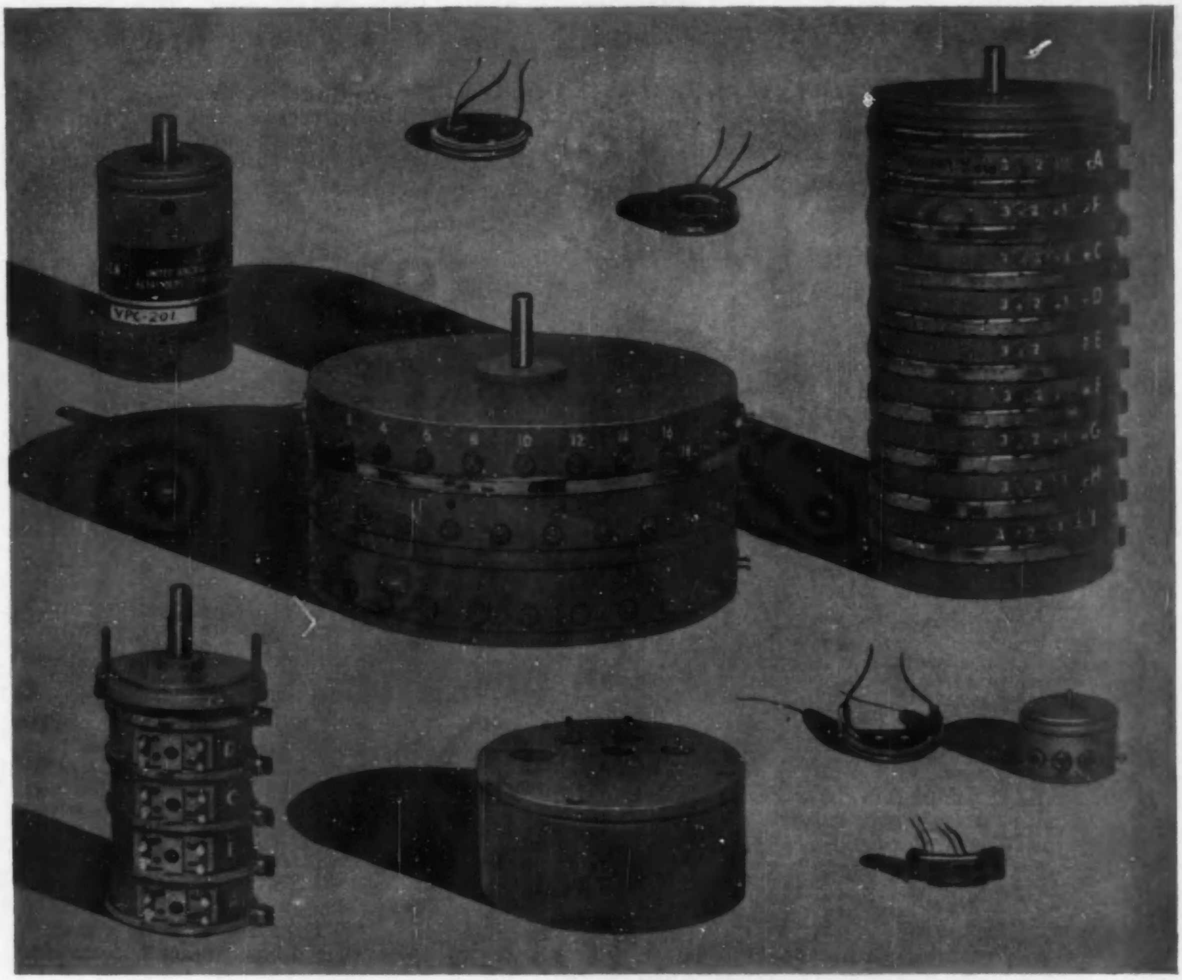
• **Where is it?**—Because of the weight restriction, the first commercial communication satellites are likely to be passive relay stations which require less onboard hardware than active ones. But that raises another problem: tracking them accurately enough with transmitting and receiving antennas so signals are not distorted.

NASA feels that this is not too much of a problem, although the agency did run into trouble tracking Echo 1, particularly when that pioneering body's tracking beacons weakened. Agency engineers have proposed this method of tracking: the government's string of Minitrack stations, which use a radio interferometer to position satellite, would predict the satellite's orbit for transmitting and receiving stations. Such gross information would put narrow band radars (located at the ground stations) onto the general area of the target. When the narrow band trackers found the satellite, they could automatically direct the sending or receiving antennas.

Telephone engineers have doubts about this. Some of them feel NASA's proposal is easier to say than to do. The communication specialists point out that unexpected movement of the satellite by solar flares or other cosmic force, or even tiny distortions of the ground antenna (such as those caused by wind) could move the communication system out of its bandwidth. And automatic tracking by conventional feedback control might not solve the problem either. What will probably be needed, said one telephone man, is a nonlinear system that has not yet been designed, one that will be pushing the frontiers of control.

To emphasize the character of the problems, a good quality 60-ft ground antenna for a commercial communication system would have a beam width 20 times narrower than the one that received bounced messages from Echo 1. The beam width is less than the structural sag in the 350-ton horn.

• **On the air**—Such control problems will be the center of attention in the



A collection of special Ketay potentiometers including single turn, multi-turn, ganged, sector, pendulum and pick-off types. Both linear and non-linear models are included.

Call on Ketay

for your Precision Potentiometer Requirements

Ketay has capabilities for designing and manufacturing specialized as well as standard precision potentiometers. Ketay can fulfill a wide range of requirements with potentiometers offering these superior features:

PRECIOUS METAL or base metal windings meet temperature coefficients, low torque and low noise level requirements.

WELDED TAPS permit high resolution since there are no shorted turns in the tap region. Ketay-designed equipment enables wire to be welded 1/5 the diameter of a hair.

OPTIMUM ACCURACY for all diameters—Ketay's exclusive servo-controlled winding machines assure constant tension and accurate spacing of turns. Conformity of 0.05% and better within a 3" diameter is an example of Ketay potentiometer accuracy.

HIGH TEMPERATURE (to 300°C) and nuclear resistance.

Ketay can supply precision potentiometers to generate functions such as sine, cosine, tangent or exponential and empirically derived curves. Units can be designed for almost any environment. Detail your exact specifications and mail to us.

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UNITED AIRCRAFT CORPORATION

NORDEN DIVISION

KETAY DEPARTMENT, COMMACK, LONG ISLAND, NEW YORK

CIRCLE 37 ON READER SERVICE CARD

WHAT'S NEW

next 18 months when government and commercial organizations put satellite communication systems on the air. It is expected that NASA and AT&T, in a joint effort, will have a system operating within 15 months for international telephony between Western Europe and the United States. The Bell System has been pushing the project because it estimates that the rising volume of international phone calls will overload the transcontinental cable under the Atlantic by 1962.

AT&T plans a satellite just one step above a passive one. Ground stations would transmit to the satellite on 6,775 to 6,875 megacycles; the satellite will shift the incoming frequency band by 350 megacycles and retransmit back to earth in the band 6,425 to 6,525 megacycles. Both the incoming spread of 100 mc and the outgoing one would be divided into two parts to provide frequency assignments of 50 mc each. A terminal in Western Europe would transmit to the satellite in the lower half of the band, and U. S. stations in the upper half. This system would provide 600 telephone circuits or one two-way TV channel.

• **Highlights**—Communication satellite plans are summarized in the table on page 35. Here are some highlights of the programs:

• NASA will launch another passive Echo satellite this year. It will weigh 660 pounds, be about 135 ft in diameter, and be constructed so that it is almost 100 times as rigid as Echo 1.

• NASA also has plans to launch an active satellite by 1963.

• U. S. Army's Project Advent will put satellites in an orbit 22,300 miles above the earth's surface, a so-called stationary or synchronous orbit because at that altitude the satellite is stationary relative to any point on the earth's surface.

• The Air Force is weighing an MIT proposal to launch a chaff belt—an area of aluminum needles—that would reflect communication signals.

• Hughes Aircraft Co.'s proposed orbiting communication system would put active satellites in a synchronous orbit as repeater stations in the sky.

• By 1963, NASA plans to set up a passive system with 20 spheres, orbiting in two orbital planes, 10 to a plane. The giant balloons launched into 1,500 mile orbits should have a life of 15 to 20 years.

• The Air Force is studying a proposal to launch a six-balloon satellite system into a 2,000-mile-high orbit. The balloons are to be tied together.

—Seth Payne
McGraw-Hill News








Japanese Instruments:

For Home Today; The World Tomorrow

TOKYO—Japan's instrument industry, which has been making rapid strides, resembles more and more its U. S. counterpart. Touring a Japanese instrument show, an American visitor is likely to see some familiar sights, many of the same kinds of equipment that would be on display at an American show such as an ISA exhibit. At Japan's sixth annual instrument show in December, McGraw-Hill News Bureau chief Sol Sanders toured the exhibits with a camera. Some of the highlights recorded by his Leica are reproduced here. They show an increasing Japanese interest in data loggers, computers for process control, and high quality instruments. Japanese industry leaders told Sanders that 1961's first marketing goal would be the expanding Japanese economy, but a push for export markets would develop soon after.

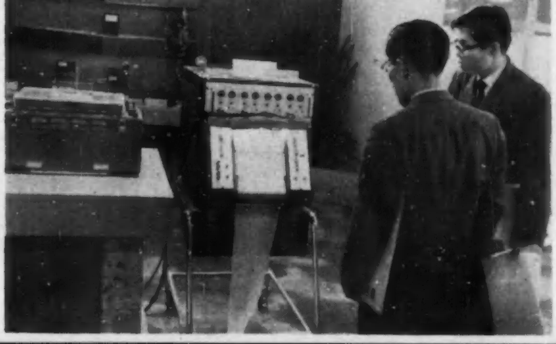
PROCESS CONTROL computer was displayed by Yokagawa Instruments Co. It looks like, and is said to have similar capabilities as, the American TRW Computers RW-300.

LARGE SCALE COMPUTER built by Fuji Denki, was offered as multi-purpose machine, for functions of data processing as well as control.

OSCILLOSCOPES built by Matsushita Electronics Co. Despite a flood of inexpensive units—some companies make oscilloscopes that sell for as little as $500—many Japanese engineers insist on importing oscilloscopes because Japanese built units are inadequate for high frequency work or for very short duration studies.

SIMPLE LOGGING equipment with numerical indicators was displayed by Kuwano Denki KK.

NEW PEN-WRITING OSCILLOGRAPH, also built by Yokagawa Instrument Co., created quite a stir with its 1 mv per centimeter sensitivity. It is transistorized, and is said to have zero drift because of Hall generator feedback. Cost: about $30,000.



TOKYO SHIBAURA (Toshiba), one of Japan's biggest instrument and electronic manufacturers, displayed a computer programmed to log variables at a refinery and to control it.

Switch to Blend—*Electronically*

West Coast oil companies start 1961 with new electronic gasoline blending systems. The new controls mean more accurate formulations and less piping.

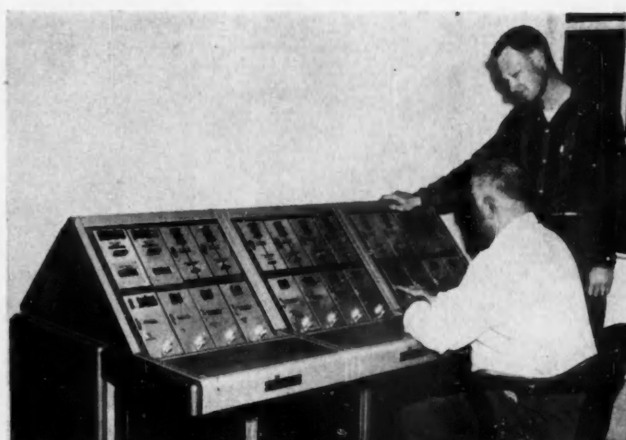
SANTA FE SPRINGS, CALIF.—The new gasoline blending system at Wilshire Oil Company's refinery here looks strange compared to those that have been previously installed in West Coast refineries. For one thing, there's much less piping; blend components are not piped to a centralized location for control. In fact, blending takes place at three sites, each close to a group of component storage tanks so there are no long piping runs from the component tanks. Control is directed from an electronic console off the blending site.

What makes this piping saving possible is a new blending system directed by electronic digital control. This one was built by B.I.F. Industries, but other digital blenders have also won acceptance on the West Coast. Late in December 1960, Union Oil Company put a blending system on line run by a digital control developed jointly by the oil company and Packard Bell Computer Co.

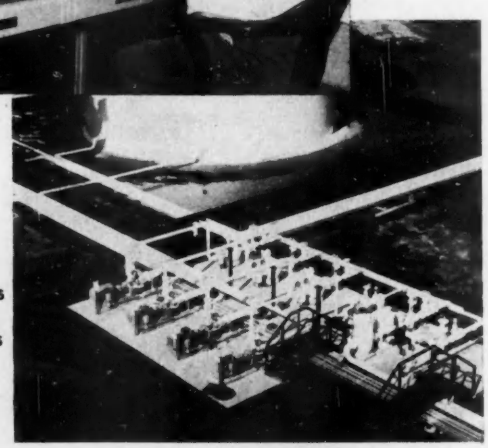
The Wilshire system system blends 12 components: eight base stocks, TEL (Tetraethyl lead), two other additives, and a dye solution—at a top rate of 3,500 barrels of product output per hour. Total product flow for the first 30 sec is accurate to ½ percent by volume for each component.

• **Start with a pot**—B.I.F. characterizes its approach as "a controlled rate, leading element system". Its leading element is a master reference voltage (from a 24 volt dc power supply) that controls blend flow rate. By turning a linear potentiometer so that the reference voltage is 24 volts, an operator sets the system to run at top capacity. For lesser blending rates, the pot is turned to generate a smaller voltage.

Each component flow rate is set by



Operator sets blending rate and components into console which directs . . .



three blending subcenters of which this is one Electronic control reduces piping required.

Take a close look at this new limit switch! It's so immune to moisture, we'll guarantee it, electrically and mechanically, for one year or 10,000,000 operations . . . whichever comes first. We call it our Super-Sealed SL2-T. If you've ever had limit switch trouble caused by water, soluble oils, condensate or *any* kind of moisture, you'll want complete details. Call, write or wire.

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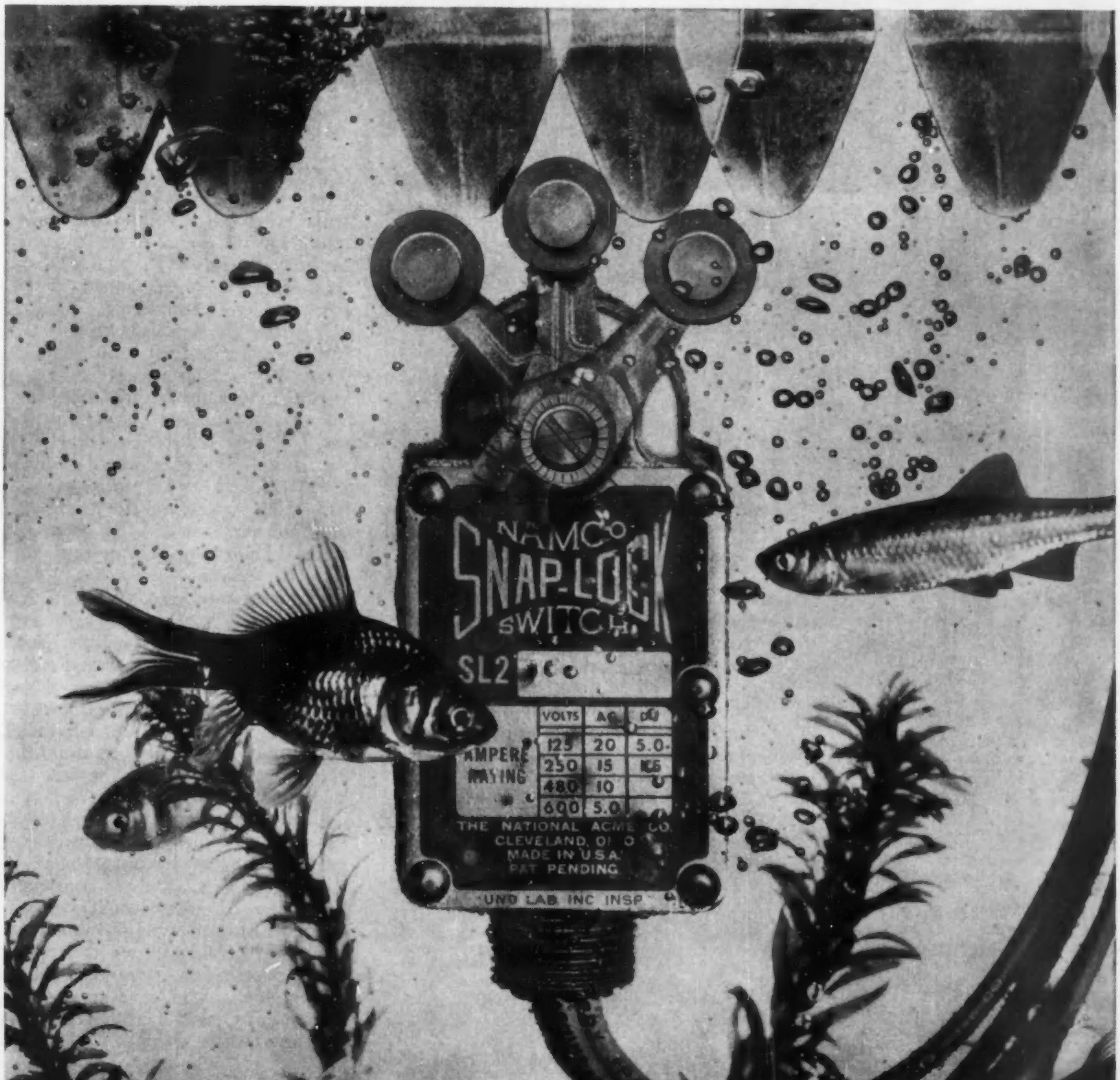
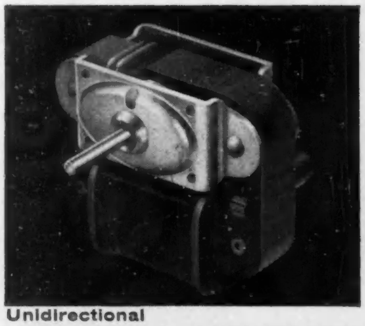
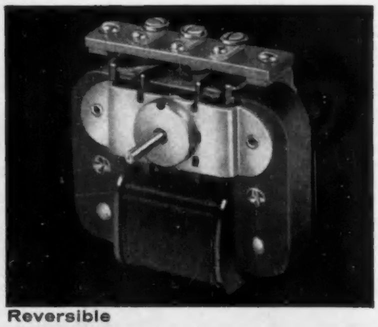
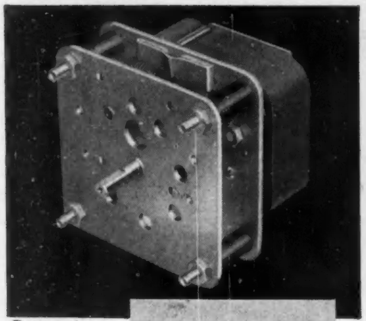
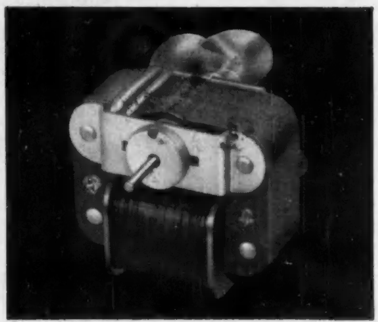


CIRCLE 43 ON READER SERVICE CARD


Unidirectional


Reversible


Geared


Synchronous

an individual linear potentiometer. After the integrated blending rate has been dialed in, the operator makes percentage settings for each component going into the blend.

The reference voltage, regulated by a Zener diode, feeds a transistorized saturable core multivibrator that converts it to a pulse train proportional to the voltage. At top blending rate, for example, the multivibrator converts the 24 volt dc reference to a pulse train of 125 cps. The voltage representing a component set to contribute 10 percent to the integrated blend would be converted to a pulse rate of 12.5 cps (just 10 percent of the total rate) by its multivibrator. The pulse output representing the total volume feeds a totalizer that records barrel throughput in its master module in the control console.

• **Unique stepping motor**—Control pulses representing the components are transmitted to individual differential controllers at the proper manifold site. In the controller, a unique stepping motor with a magnetic detent cyclonome translates the pulses into rotary motion. A second input to the controller comes from a Brodie positive displacement meter which measures actual flow rate.

Originally developed by Sigma for computer applications, the stepping motor has no mechanical ratchet, a feature that improves its reliability and extends its operating life. Output of the motor is fed to one side of a mechanical differential whose spider is integrated into the pneumatic controller. If the signal from the flow meter does not exactly equal that from the stepping motor, the controller takes corrective action.

• **Supplemental acts**—Wilshire has separate report-back circuits to supplement the blending system. Such variables as actual flow, control valve position, differential pressure, and line pressures keep the operator posted. Instantaneous flow ratios are not maintained since the oil company stores the entire output. What is controlled is total product flow.

B.I.F. designed the system so that formulations could be made by punched card or by direct coupling with a process control computer. Since the computer could be programmed to analyze pipeline output and calculate required corrections in component flows, it could be used if the final blend is ever pumped directly into rail cars or tankers without intermediate storage.

—Michael Murphy
McGraw-Hill News

Mechanization Breaks Down in the Soviet Union Too

"Automation is the wings of the seven year plan", boasts a sign in a Russian plant, but the plant management finds it creates as many problems as it solves.

MOSCOW—

The "Hammer and Sickle Plant" in Kharkov is a Soviet showplace factory that is a favorite on the tour list for foreign visitors. Producing diesel engines on automatic machine tools, the plant reported worker productivity jumped four and a half times in the past ten years. But a giant step at the start of 1960 has caused some indigestion, the newspaper Ekonomicheskaya Gazeta reports. Most serious pain, says the paper, stems from the fact that the plant is now operating at only half capacity, and the reasons for the downtime are far from being solved. Apparently the Kharkov installation is not the only one having such troubles.

Originally, the plant was set up to produce a primitive threshing machine, later it was converted to produce diesel engines for self-propelled agricultural machines. Since the beginning of 1960, some of the key components – cylinder blocks, cylinder heads, and flywheels, for example – have been produced on continuous manufacturing lines.

In one mechanical shop, 11 automatic lines are in operation. On a line that produced cylinder blocks, some 50 machines run automatically. And the plant is scheduled to install 30 more automatic lines within two or three years.

• **Who's to blame**–What's behind the trouble is faulty planning that ranges from bad supply of materials through poor scheduling to piecemeal mechanization. Here's a rundown of the troubles reported by Ekonomicheskaya Gazeta:

▶ **Faulty parts**–The plant is repeatedly slowed by the breakdown of minor but essential parts such as boring bits and tool spindles. Spare parts are often not available. In one case that was cited, the entire automatic cylinder block production line was shut down because of one broken spindle on one machine.

▶ **Diversion of materials**–The government requires the plant to do

WHAT'S NEW

. . . crankshafts are hammered out by hand; and manual machines pace automatic lines . . .

casting and forging work for other enterprises—including an automobile factory and a plant that makes dumbbells for weight lifters. Meeting the needs of these other manufacturing units, the Kharkov diesel plant sometimes fails to meet its own.

▶ **Hangovers from the past**—While automatic lines have taken over some plant operations, others close by are still literally done by hand—thus slowing the whole overall process. For example, crankshafts are still hammered out by a man with sledgehammer. "If the crankshaft breaks, its quality was poor; if it doesn't break, nobody knows whether it is good or bad", the newspaper complained.

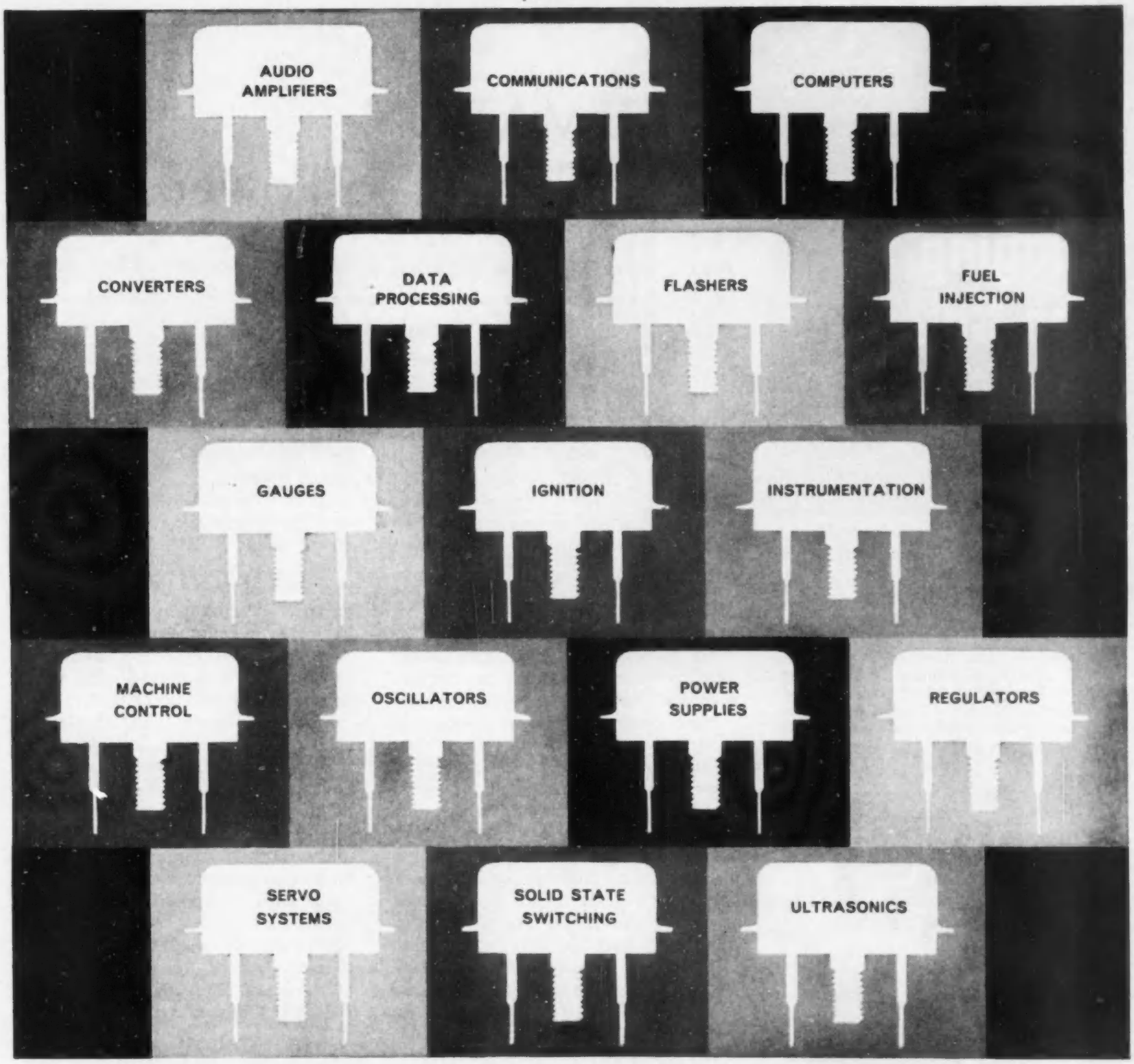
To make matters worse, 20 million rubles worth of equipment for an automatic casting shop that could make the crankshafts uniformly and automatically has been laying idle waiting for installation. The reason: the casting shop isn't ready yet, although under construction for over six years.

▶ **Bad design**—Even in the automatic parts of the plant, some portions of the production process have been left out by the systems designer. And the equipment itself lacks flexibility. For example, the first operation of the cylinder head production line is performed on a nonautomatic cutting machine so that the entire automatic line that follows is paced by this manually-operated cutter. Nonautomatic machines are also used in polishing and grinding operations, interspersed in so-called automatic lines.

Materials handling techniques are lagging, too. The newspaper found that one worker had to manually load half-finished forms, weighing 130 pounds, onto the "automated" flywheel production line.

Most severe criticism, however, is the automatic lines' lack of flexibility. Those running were designed to make the 53 horsepower CMD-7 engine. But this year the plant was supposed to start producing a larger 75 horsepower CMD-14 engine. But it can't be done without what the newspaper calls a very thorough changing of the automatic lines. Work has already been under way for six months to change the automatic lines to build the new engine.

—Ernest Conine
McGraw-Hill World News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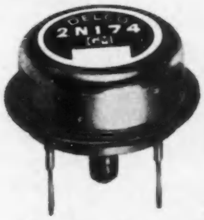
ULTRASONICS


2N174

SYSTEMATION: From Cement to Power

Allis-Chalmers has finally found a formula that capitalizes on its industrial process know-how to bring the old-line equipment producer into the advanced control field.

MILWAUKEE, WIS.—
Teams of engineers are fanning out from Allis-Chalmers Manufacturing Co.'s home office these days and telling industry about something A-C calls Systemation. This word can't be found in the dictionary, but A-C has a 47-word definition for it:

> "Systemation is the service of combining the basic equipment of industrial process systems with proper measuring, sensing, and actuating instrumentation to display, record, compare, compute, or optimize control signals or commands and provide continuous maximum output of the system consistent with prudent investment in equipment and instrumentation."

What this jawbreaker means is that A-C, one of the country's biggest industrial process engineering firms, now has its own electronic control systems capability and would like to sell the package to anybody who's interested.

The first "Systemation" contract—a $750,000 computing-control job using an RCA 110 computer for an existing power plant operated by Gulf States Utilities Co.—was announced recently (CtE, Jan. '61, p. 153). Discussions are currently under way with a number of other companies, and a metal rolling application for Systemation is said to be a good prospect.

• **On the inside, buying out**—Allis-Chalmers has been building industrial systems for years, and has supplied all kinds of basic equipment for industry, including a lot of controls. But until last summer, it had to turn to outside suppliers when a contract involved data logging functions or digital equipment for advanced electronics applications. Some of A-C's biggest competitors, meanwhile, already had this capability within their organizations.

By using outside suppliers for the electronics portions of its systems, A-C was faced with problems in maintaining responsibility for the upkeep and updating of these portions over the long haul. "These 'weekend marriages' were sometimes exciting," says an Allis-Chalmers executive. "But they didn't last." A-C never seemed to be able to crash the business with a steady approach.

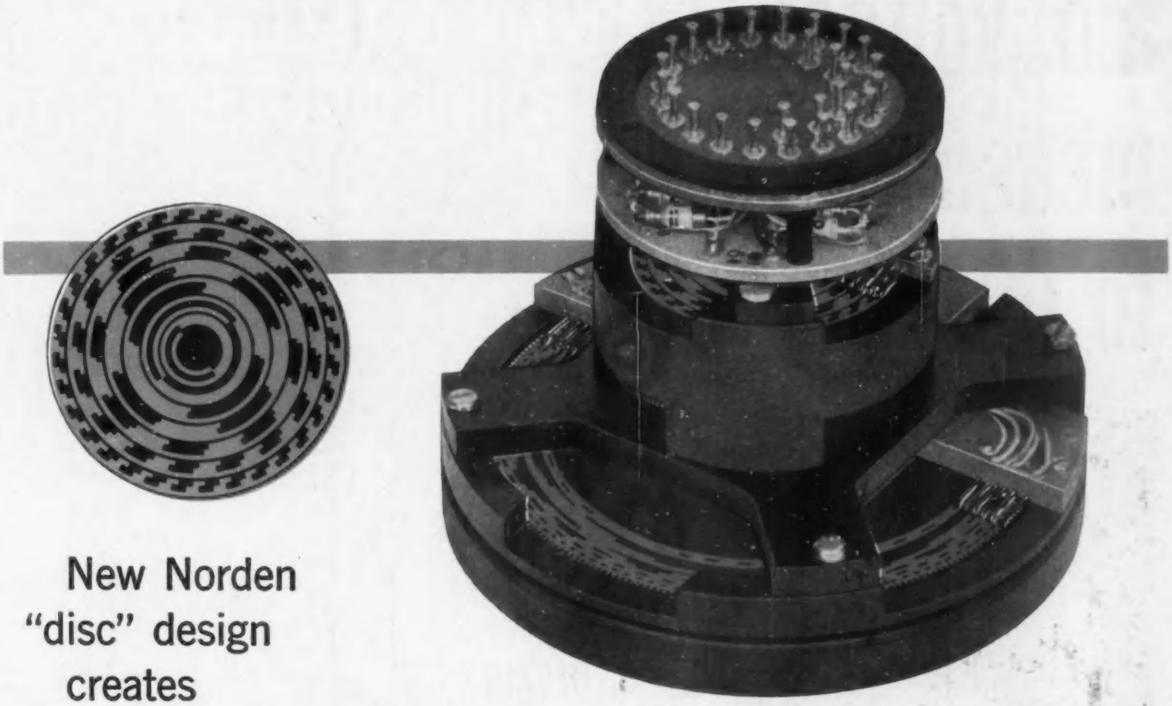
At the same time, Allis-Chalmers was "putting people into business" by giving them a lot of basic process knowledge. So the company looked at the possibility of building its own group of electronics systems specialists from the ground up—it had been using a computer in design problems for several years—but decided this would be a long and arduous task.

• **Shopping spree**—After thinking it over for some time, Allis-Chalmers began shopping in earnest about 18 months ago for a permanent alliance. Its executives talked with a host of leading electronics companies—one estimate puts it at more than 50—and found that many were eager to be associated with a company that had built up such a tremendous fund of industrial process knowledge.

Last summer (CtE, Aug. '60, p. 44) A-C announced acquisition of a half interest in Consolidated Systems Corp. of Monrovia, Calif., a wholly owned subsidiary of Consolidated Electrodynamics Corp. The parent firm of CEC, in turn, is Bell & Howell Co. of Chicago, photographic and office equipment manufacturer.

CSC which had cut its teeth primarily on military jobs, had experience in designing complex data processing systems used in advanced applications like jet engine testing, missile checkout, wind tunnel testing, etc. It had designed and built a lot of sensing instruments to go along with them but was also a big user of CEC's products. Originally, CSC started out as a small group within CEC to accomplish particular tasks that a customer wanted. It became a division in 1954, now has over 500 employees, of whom a third are technical. Both Allis-Chalmers and CSC were dedicated to the systems approach, and Bell & Howell's experience in working with optics was a plus factor.

• **An organization is people**—A-C



New Norden "disc" design creates

High count, multiple turn Gray encoders ...without indexing mechanisms

Norden engineers have succeeded in incorporating double brush logic in a Gray encoder, model ADC-16-GRAY, achieving multiple turn capabilities and high resolution per turn ... without the need for between-stage indexing mechanisms.

Norden ADC-GRAY code units:

- meet or exceed military specifications.
- assure freedom from error due to positional ambiguities.
- are the smallest multi-turn Gray encoders available, and store nearly twice as much in a given diameter as units using a pure binary code.
- eliminate ambiguity situations caused by cross-coupling, simplifying telemetering problems such as may arise in space satellites.

Norden offers several models in Gray-code encoders with a total count range of 2^8 to 2^{16}. Review your requirements and send for detailed specifications and drawings or call TRinity 4-6721.

TYPICAL MODELS	TOTAL COUNT	REVOLUTIONS FOR FULL COUNT	DIAMETER
ADC-16-GRAY	65536	64	3.25
ADC-ST10-GRAY	1024	1	3.25
ADC-ST9-GRAY	512	1	2.25
ADC-ST8-GRAY	256	1	1.75

UNITED AIRCRAFT CORPORATION
NORDEN DIVISION
NORWALK, CONNECTICUT

CIRCLE 49 ON READER SERVICE CARD

moved quickly to implement its new action. In a matter of days, CSC engineers were behind desks in the Industrial Systems Dept. of A-C's Industrial Equipment Div. Industrial Systems, headed by B. G. Witty, consists entirely of application engineers. Their job is to apply Allis-Chalmers equipment to systems and coordinate and handle the whole project.

Thirty-six year old L. Merle Wilson, with CSC since 1954 and a specialist in digital systems and communications, was named manager of CSC's Milwaukee operation. Two other young engineers—M. B. Edwards (29), who had a background in applying electronics to chemical processing, and R. L. Felberg (34), an instrumentation man, were also dispatched to Milwaukee.

In addition to three full-time CSC men in Milwaukee, three others now shuttle back and forth between there and Monrovia, and John C. Alrich, assistant director of CSC's Industrial Systems Engineering, is a frequent visitor to Wisconsin. These men coordinate mainly with W. Ed Korsan, 46-year old assistant manager of A-C's Industrial Systems Dept.

Coordinating at CSC's end is George G. Brooks, 34, formerly sales manager of A-C's Control Dept., who was sent to Monrovia and named director of Industrial Systems Engineering there. He provides first-hand knowledge of A-C's workings, and a number of engineers work with him.

William Terry, Jr., general manager of A-C's Electrical Depts., coordinates A-C's Industrial Systems Dept. with the controls, motor-generators, and Norwood (motors) groups and reports to William M. Wallace, vice-president and general manager of the Industrial Equipment Div. George Saar, general manager of the Mechanical Depts., also reports to Wallace and works with Terry. Wallace cooperates with vice-presidents heading the Nuclear Power and Power Equipment Div. of A-C's Industries Group. The new look at Allis-Chalmers is obviously a young look, too. Even Vice-President Wallace is just 46; Terry is 38.

• **Three-barrel attack**—This group started out to attack three specific areas of industry: power generation, metal rolling, and dry processing. These three areas are vital to Allis-Chalmers' business. A-C is so diversified that it does not attempt to sell with a product approach but rather with an industries approach: to try to determine present and future needs

(Continued on page 173)

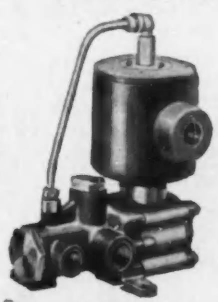
ASCO SOLENOID VALVES ARE ENGINEERED TO MISSILE GROUND SUPPORT REQUIREMENTS

Tight Shut-Off at Pressures to 3000 PSI, Temperatures to Minus 350°F.

ASCO now brings you a family of solenoid valves, specially designed for missile applications with tough environmental or operational requirements. Two, three and four way valves are available with standard, explosion-proof or watertight solenoids; sizes range from ⅜" through 2½". Fluids handled include air, liquid oxygen, helium and nitrogen (liquid and gaseous). Valves can be supplied with continuous duty coil windings for 24 volts D-C, and for any other commercial voltages required. All types are packless (hermetically sealed), providing tight shut-off, with no external leakage to atmosphere.

Two Way Valves . . . normally open or normally closed, easily handle fluids at pressures to 3000 psi, temperatures to -350° F. Valves are stainless steel with teflon discs; most sizes are available with AN connections (Main Illustration-Bulletin 8223X).

Three and Four Way Valves . . . are suitable for piloting cylinder operated valves. Three way valves are also utilized for controlling single acting cylinders, and diaphragms; four way valves are used for controlling double acting cylinders. Unique poppet type seats and discs assure tight seating at pressures to 750 psi, temperatures to -65° F. Valve shown below (Bulletin 8344X) is suitable for 4 way applications, or may be used for 3 way installations by plugging one cylinder connection.



Proposals are submitted upon receipt of specifications—or an ASCO Engineer can help you in solving your ground support valving problems.

For additional information on ASCO Solenoid Valves for Missiles, write for Publication V5056.

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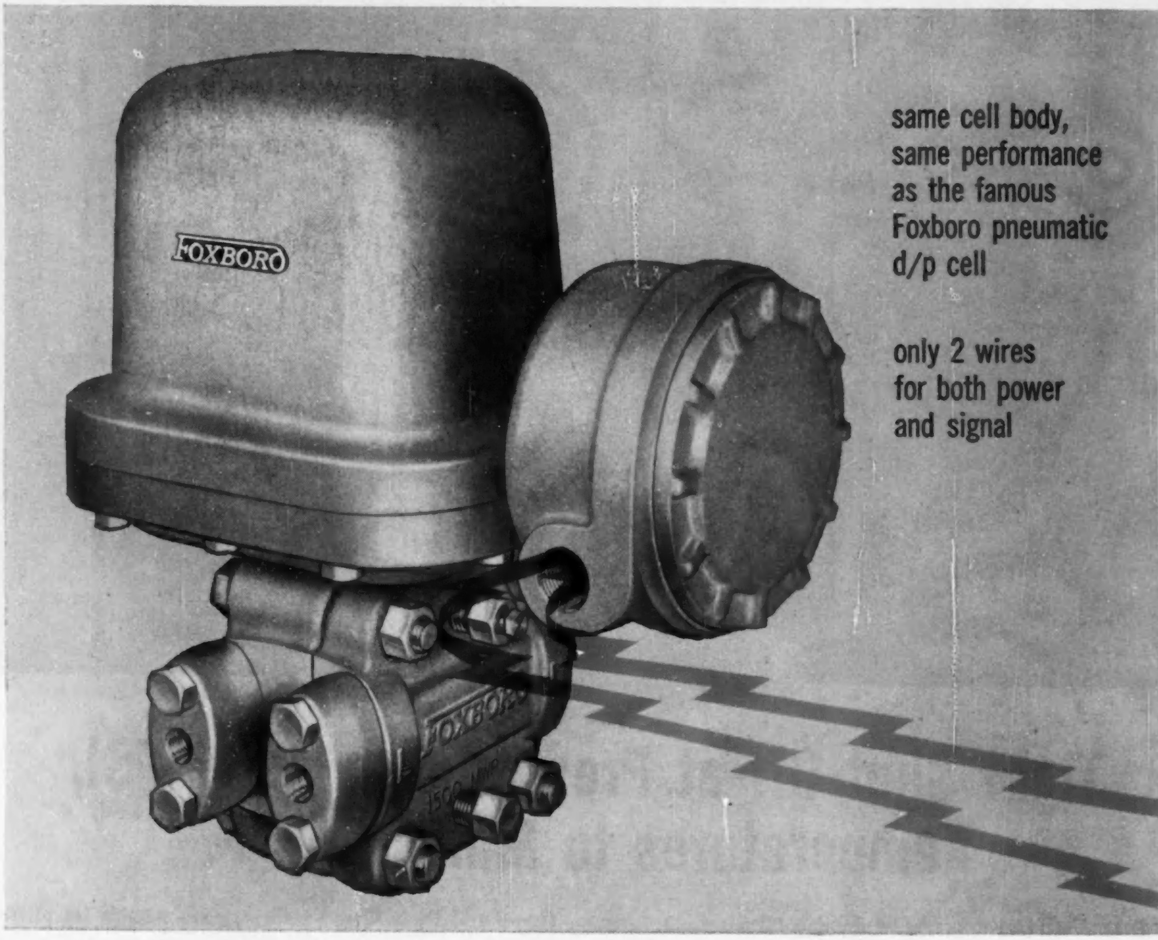
CIRCLE 51 ON READER SERVICE CARD

introducing the Foxboro electronic d/p cell* transmitter



The Foxboro electronic d/p cell transmitter and this Foxboro pneumatic d/p cell transmitter use the identical cell body. Only the top transmitting mechanism has been changed.

Yes, Foxboro has taken its famous pneumatic d/p Cell and added the benefits of electronic transmission. It's the new Foxboro *electronic* d/p Cell transmitter. Look at the results:

- both power and signal travel over the same pair of unshielded wires — no field power supply required
- pressure, flow, and level transmission up to several miles without lag
- true force-balance design for lowest displacement — highest overrange protection
- high level 10-50 ma d-c signal provides powerful rebalancing force
- adjustable ranges from 5" to 850" water with external zero adjustment — working pressures of 1500 and 6000 psi

And, of course, you get the same positive overrange protection, the same high sustained accuracy, the same rugged construction that has always been standard with the Foxboro d/p cell transmitter.

If you're thinking "electronic," it will pay you to investigate this important instrument in the Foxboro Electronic Consotrol* family. Get in touch with your Foxboro Field Engineer for complete details, or write for Bulletin 21-10. The Foxboro Company, 852 Neponset Avenue, Foxboro, Massachusetts.

**Reg. U.S. Pat. Off.*

FOXBORO

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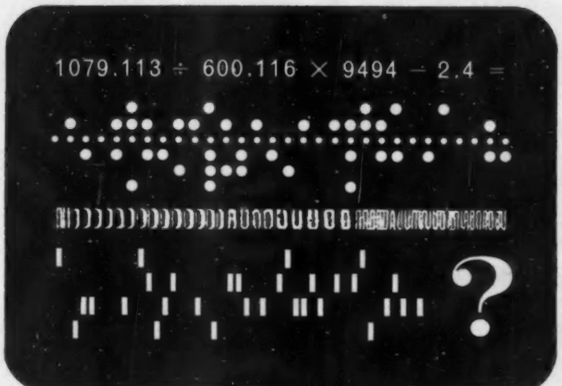
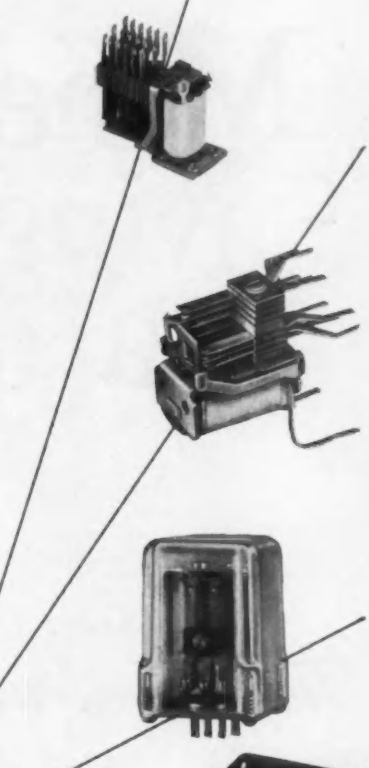
Nothing is lost in the translation with Benson-Lehner's new Machine Language Translator. What is gained, however, with this new solid-state instrument is the ability to translate machine languages. The Translator will automatically convert data in one digital code or form to, 1) output in another digital code or form, or 2) to a signal suitable for input into any Benson-Lehner Electroplotter or similar device. Translation speeds are dictated by the input and/or output modes, i.e., operating speed in conversion of digital magnetic tape to graphs is limited by the speed of the graphing instrument. If yours is a problem in converting digital data to graphs or getting any format of recorded digital data to talk to any other format, let us know. We will make up one of these for you...fast. Write to: **benson-lehner** *corporation, 1860 Franklin Street, Santa Monica, California.*



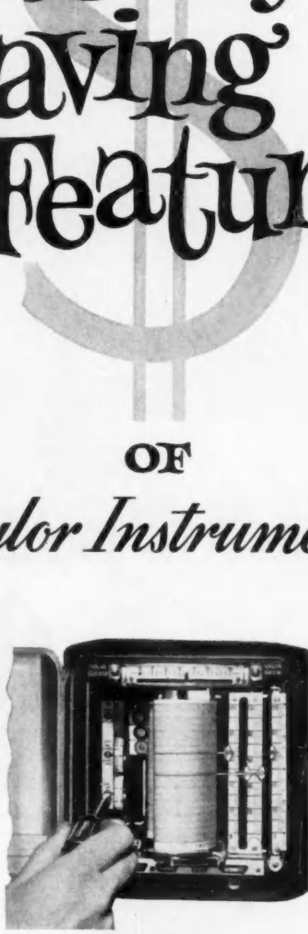


ANOTHER

Money Saving Feature

OF

Taylor Instruments



FRONT ADJUSTMENTS

First introduced in miniature instrumentation by Taylor, the front adjustment feature of TRANSCOPE* Recorder-Controllers—pneumatic or electronic—is a real time and money saver.

No longer is it necessary to have one operator in back of the control panel to adjust the controllers and another in front to tell him the results—or worse, to have to do the job alone. Now *one* man makes the controller adjustments from the *front* of the recorder. He can see what he is doing, and the results, because record and set point are side by side and always in view. He does the job easier, faster and better.

All adjustments, including Gain, Reset and PRE-ACT* responses are calibrated in specific units and are made with a screwdriver.

This elimination of 'blind adjustments' is another example of the careful attention to detail that has gone into the design of the Taylor TRANSCOPE line of Instruments. Important details that help lower your processing costs while maintaining the highest standards of product quality.

▾ ▾ ▾

Ask your Taylor Field Engineer to demonstrate the TRANSCOPE *90J (Pneumatic) or 700J (Electronic) Recorder. Or write for* **Catalog 98286** *(90J) or* **98335** *(700J). Taylor Instrument Companies, Rochester, N. Y., or Toronto, Ont.*

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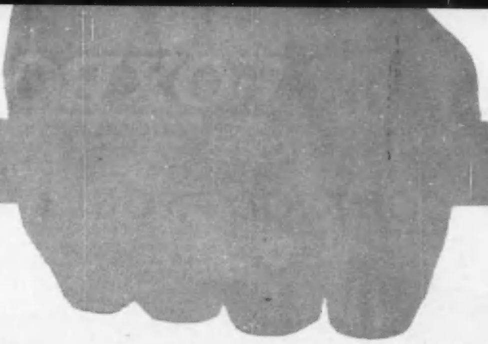
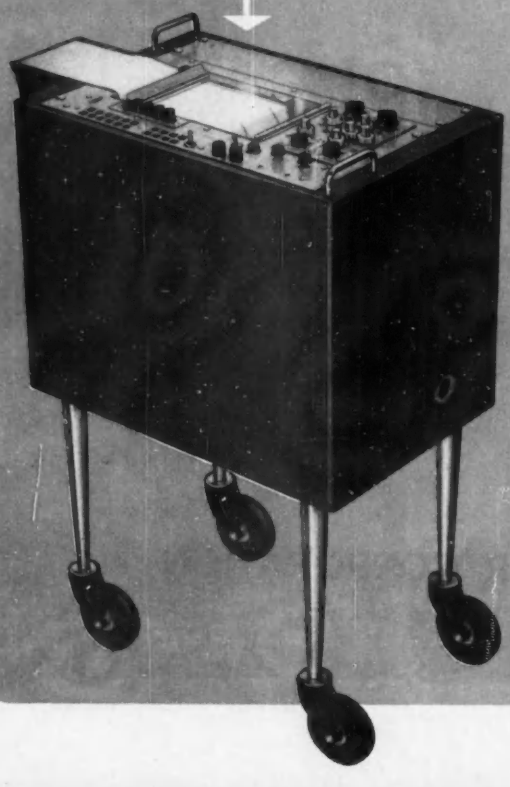
Taylor Instruments
MEAN ACCURACY FIRST



get the size, specs and mobility you need with

SANBORN RECORDERS



2 Channels . . . 35" high mobile cart . . . choice of 4 plug-in preamps

Interchangeable plug-in "850" type preamplifiers in Carrier, DC Coupling, Phase Sensitive Demodulator and Low Level types, for inputs ranging from microvolts to hundreds of volts . . . internal MOPA available when carrier or chopper excitation is required . . . heated stylus, rectangular coordinate recording on 50 mm wide channels . . . transistorized circuits . . . frequency response to 125 cps within 3 db, at 10 mm peak-to-peak. Model 297 can also be used in optional portable case or rack mounted in 10½" of panel space.

Two 50 mm wide channels . . . separate floating input DC amplifiers . . . 4 chart speeds . . . mv or volt inputs

Operate this 1-cubic-foot recorder vertically, horizontally, or tilted at a 20° angle on carrying handle. Inputs are floating and guarded . . . 12 sensitivities from 0.5 mv/mm to 20 v/cm . . . response DC to 125 cps within 3 db, at 10 div peak-to-peak . . . max. nonlinearity 0.25 mm . . . common mode rejection 140 db min. DC . . . built-in 10 mv calibration signal and electrical limiting . . . internal 1 sec. timer . . . monitor output connectors for each channel. Galvanometers are rugged, low impedance type with velocity feedback damping; most circuitry for each channel is mounted on a single, easily serviced card.

1 Channel . . . 20 lbs., briefcase size . . . 10 mv/div DC Model . . . 10 uv rms/div AC strain gage Model

Extremely compact, highly versatile recorders for general purpose DC inputs (Model 299) and AC strain gage recording (Model 301). Two chart speeds: 5 and 50 mm/sec . . . inkless, rectangular coordinate recording . . . response from DC to 100 cps within 3 db, at 10 div peak-to-peak . . . gain stability better than 1% to 50°C and for line voltage variation from 103 to 127 volts. Model 299 has balanced to ground input, 10 switch-selected sensitivities, calibrated zero suppression. Model 301 has wide sensitivity ranges, can be used with strain gages and inductive transducers, provides excitation voltage of approximately 4.5 volts rms at 2400 cps, and has uncalibrated zero suppression.

For complete details contact your nearest Sanborn Sales-Engineering representative. Sales representatives are located in major cities throughout the United States, Canada and foreign countries.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts

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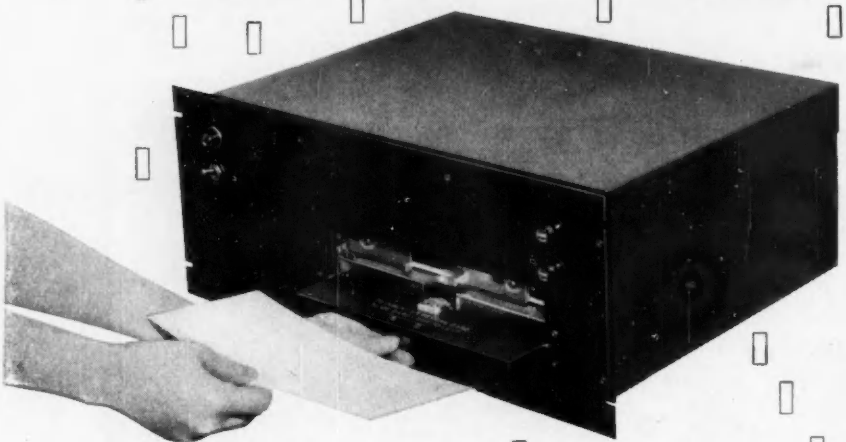
DIRECT CONTROL PROGRAMMING



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Automatic equipment designed to provide direct control, without coding or decoding, for as many as 85 individual load circuits, through 30 or more different steps of an industrial process.

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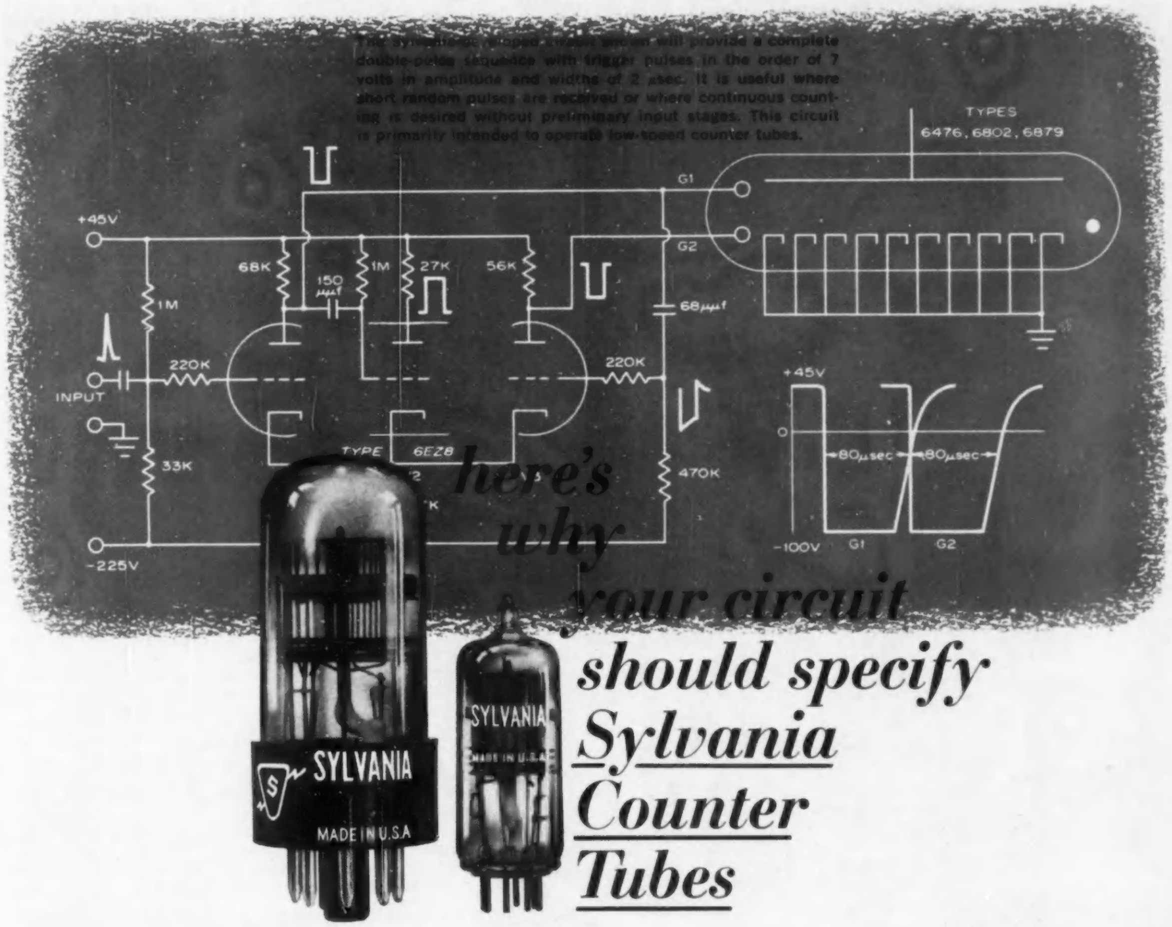
Programming equipment operated by punched tape is also available. Modular design permits addition of accessory banks of memory-type load relays. Industrial Timer Programmers are now in use for the automatic control of steel and aluminum blooming mills, structural steel fabrication, batching solid rocket fuels, and many other industrial processes.

Complete information in Bulletin 100, sent on request. Write or phone.

INDUSTRIAL TIMER CORPORATION

1401 McCarter Highway, Newark 4, New Jersey



here's why your circuit should specify Sylvania Counter Tubes

Imagine a device so versatile it can *count . . . measure . . . monitor . . . program . . . sample . . . sort . . . index . . . scale . . . tabulate*. One that combines actuating and direct readout functions. And provides the following extraordinary results: significant circuit economies, compact equipment design and improved circuit reliability. The device? Sylvania Decade Counter Tubes!

Sylvania Cold Cathode Decade Counter Tubes provide visual readout from a sharply defined ion glow moving on a peripheral ring of 10 output cathodes around a common anode. They also feature add-subtract capabilities, low power requirements and low initial cost. *Sylvania Counter Tubes* offer high reliability even under long periods of standby operation – the result of improved design and rigid manufacturing control.

Measure the advantages of *Sylvania Decade Counter Tubes*. Count on your Sylvania Sales Engineer for full data and engineering assistance. For the informative Decade Counter Tube Handbook, contact your Sylvania Industrial Tube Distributor. Or, enclose 15¢ to Electronic Tubes Division, Sylvania Electric Products Inc., Dept. 132, 1100 Main St., Buffalo 9, N.Y.

Sylvania Types	Total Anode Current (mA) Min.	Total Anode Current (mA) Max.	Min. Anode Supply Voltage (Vdc)	Min. Double Pulse Amplitude (V)	Min. Double Pulse Width (μsec)
0-4KC 6476 (T-11), 6802 (T-9), 6879 (T-5½)	0.3	0.6	350	—75	60
0-100KC 6909 (T-9), 6910 (T-11), 7155 (T-5½)	0.6	0.8	400	—85	4

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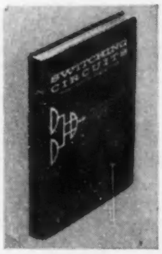

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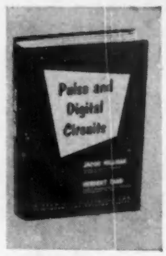

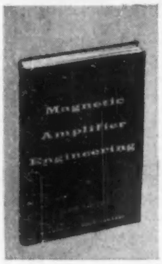

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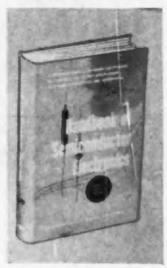

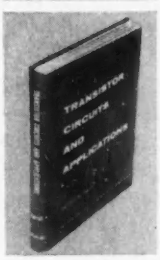

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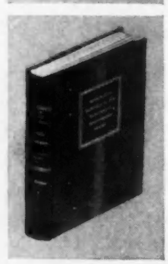

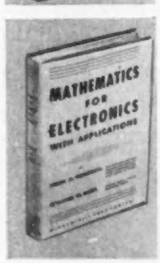

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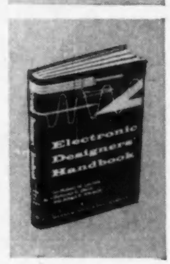

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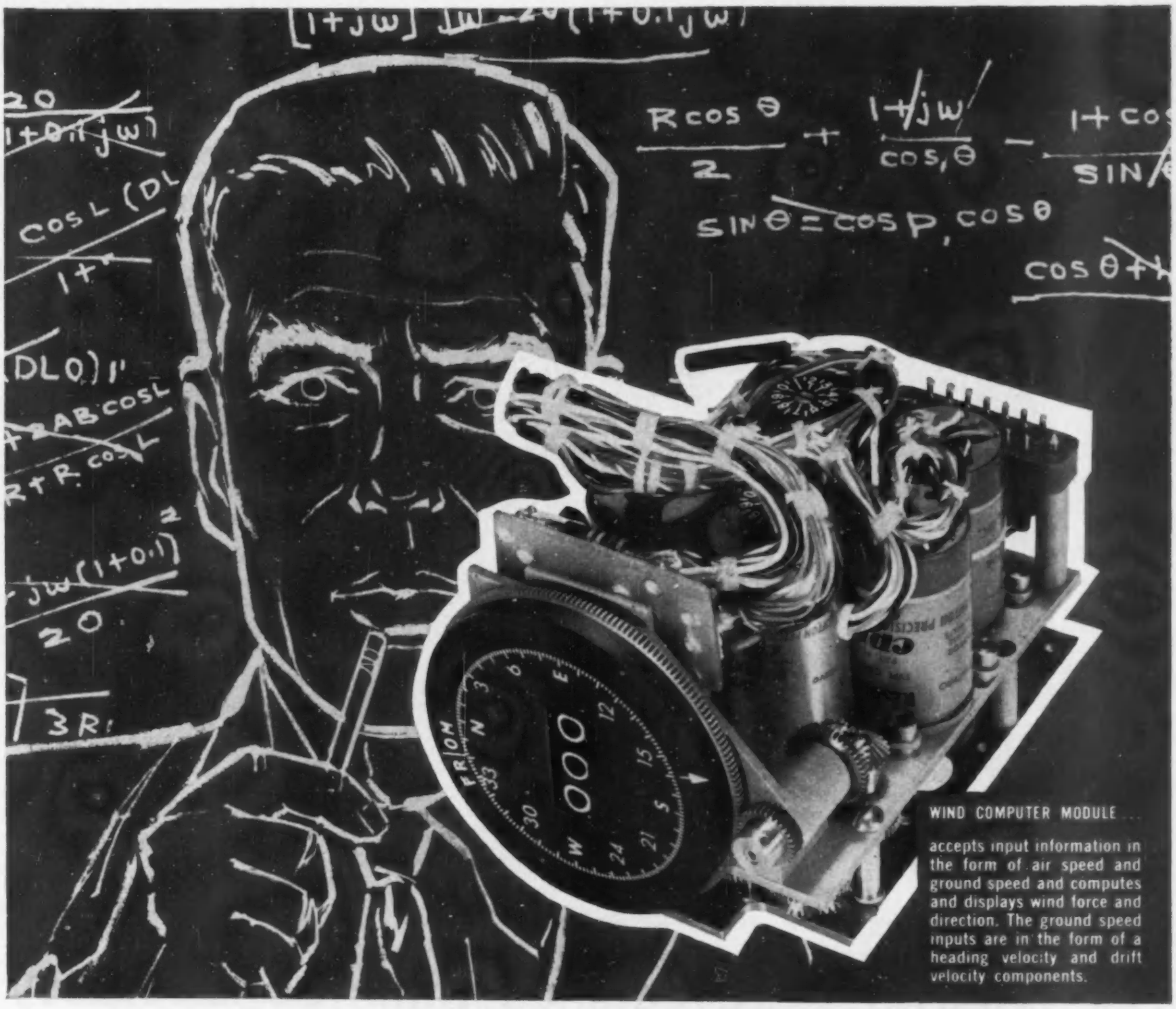

WIND COMPUTER MODULE . . .

accepts input information in the form of air speed and ground speed and computes and displays wind force and direction. The ground speed inputs are in the form of a heading velocity and drift velocity components.

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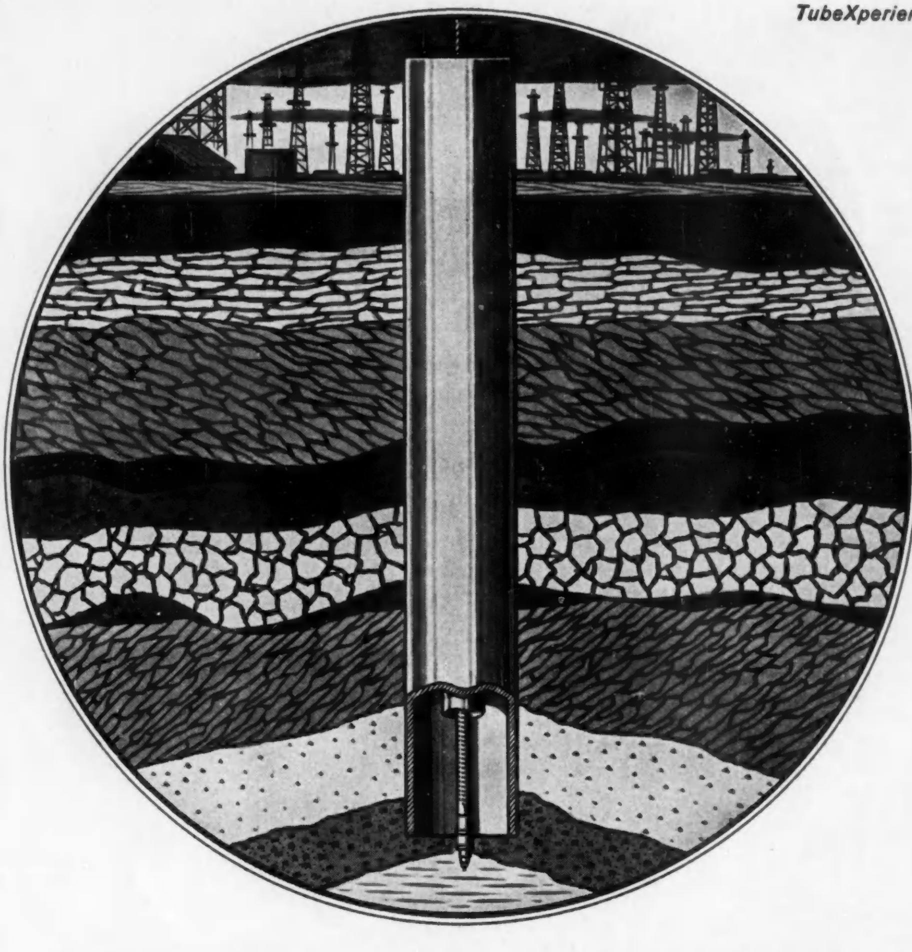

Deep well pressure readings within .05% accuracy with help of Superior Ni-Span C* Bourdon Tubing

Accurate down-well pressure readings, indicating changes of only 1 to 4 psi at bottom-hole pressure of 2000 psi, are hard to get, but extremely important. They demand a pressure gage accuracy of at least 0.1% to make the vital engineering calculations based on them of any value.

To achieve this accuracy and better it, Superior was asked for help in selecting the Bourdon tube material for an improved bottom-hole measuring device. After careful study, its metallurgists recommended Ni-Span C nickel-chrome alloy for the Bourdon tubes. This material was chosen for its relative insensitivity to temperature changes, coupled with superiority in operating temperature, mechanical hysteresis, and elastic drift; also for its fatigue resistance and spring properties.

The customer followed the suggestion and now this gage, which is unique in bottom-hole pressure instruments for the reason that it utilizes a helix-wound Bourdon tube to transmit directly the effects of pressure to a recording stylus, is rated 0.1% accurate. In fact, with special care in operations and calibration, it can measure within .05% accuracy.

NI-SPAN C TUBING NOW STANDARD AT SUPERIOR

Ni-Span C redraw stock is now in inventory at Superior, available for immediate production in a range of sizes from .010 in. to ⅝ in. OD, up to .125 in. wall max., and from ⅝ in. to 1⅛ in. OD in wall thicknesses up to .035 in. max. Shaped tubing can be produced to customers' prints. Perhaps you have an application that can benefit from its unusual properties. Write for Data Memorandum No. 19. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

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The big name in small tubing

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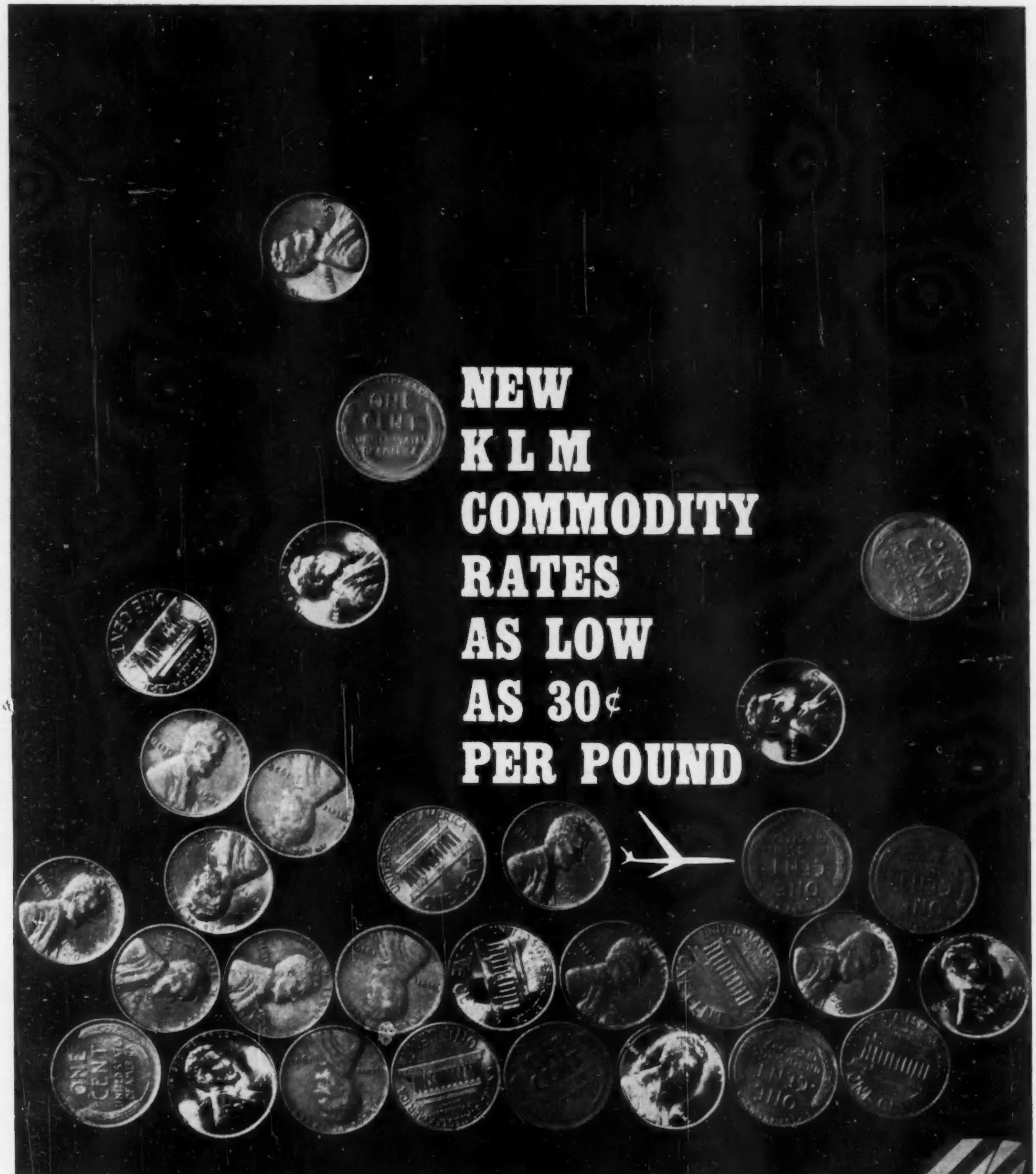
All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST



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WIRE AND CABLE ROUND TABLE

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You have asked . . .

Q. Your natural-color polyethylene for high-voltage insulation, ALATHON 3B, NC10, has been around for several years now. Have you introduced a better resin?

A. No . . . nobody (including us) has been able to match the resistance of ALATHON 3B, NC10, to combined corona and mechanical stretching (bending) under a variety of conditions. The search for a successor may be academic since we have never had a failure in any of our 15KV cables insulated with the 3B resin. Nevertheless, eternally optimistic about maintaining a lead, we have lots of new compounds under test. If one looks better, we'll be in touch with you.

Q. If ALATHON 3B is so good, tell me how I can be sure of getting its outstanding properties without naming brands?

A. Rely as you ordinarily do, on the judgment of responsible cable manufacturers. There is no simple way yet, outside of our published electro-mechanical stress-crack test, or some equivalent way (not all of which are reproducible) of separating resins of superior electrical life from others of identical melt index and density. Nevertheless, for the present, it will narrow the field somewhat to specify a melt index of 0.2 to 0.4 and density in the general range of 0.92.

Du Pont does not manufacture wire and cable, but supplies thermoplastic resins to the wire and cable industry.

POLYCHEMICALS DEPARTMENT

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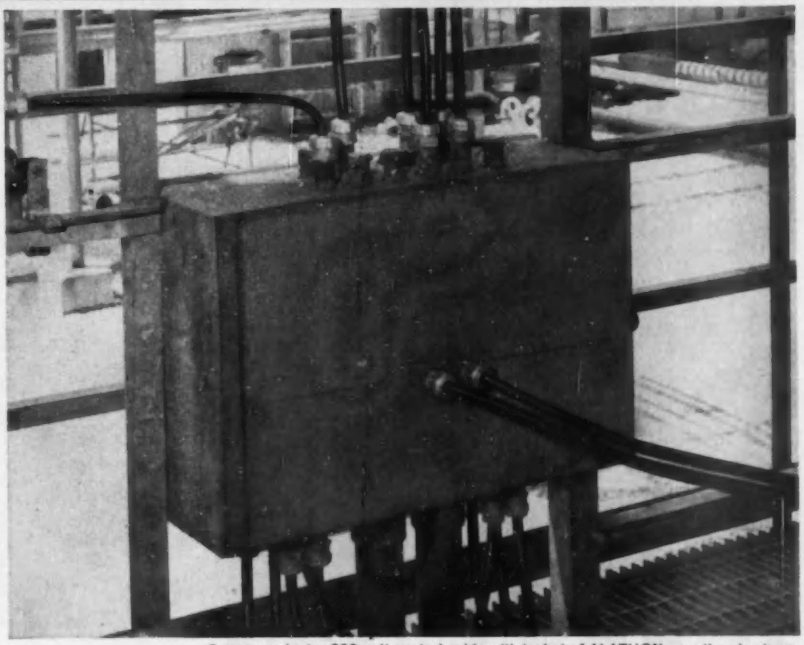


Seven-conductor 600-volt control cable with jacket of ALATHON over the aluminum sheath offers necessary corrosion protection for chemical plant hook-up.

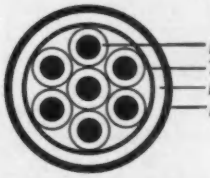
General Cable uses ALATHON® and ZYTEL® for unique control cable construction

The problem of acute corrosion attack on metal conduits has been licked at a Texas chemical processing plant. A unique control cable construction, utilizing a 0.032″ jacket of Du Pont ALATHON 4, BK-30, polyethylene resin over the aluminum sheath, has solved the problem. The cable is manufactured by General Cable Corp. of New York.

The jacket of ALATHON completely protects the aluminum sheath from the corrosive elements in the air. In addition, it also provides additional electrical and mechanical protection to the cable, and allows quick and neat installation.

The 0.020″ primary insulation over the seven conductors in this 600-volt cable is also ALATHON 4, BK-30. This black, weather-resistant type of insulation was used to protect the cable at outside terminations in the open plant structure. Over the primary, a thin 0.004″ secondary insulation of ZYTEL 37X nylon resin is used for mechanical protection at termination points. The skin of ZYTEL, which is also weather-resistant, completely protects the cable from rough handling and the abrasion found in crowded junction boxes.

Find out how insulation and jacketing of the Du Pont plastics may give you installation savings. Consult your wire and cable manufacturer, or write: the Du Pont Company, Dept. CE-2, Room 2507A, Nemours Bldg., Wilmington 98, Del. In Canada: Du Pont of Canada Ltd., P.O. Box 660, Montreal, Quebec.



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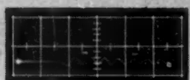
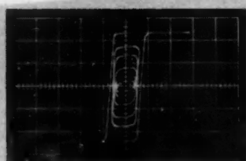
CIRCLE 65 ON READER SERVICE CARD

You can do MORE with the NEW TEKTRONIX C-12 CAMERA than you can with any other Oscilloscope Camera

...picture this



1 KMC damped oscillation (single shot at 2 nsec/cm).

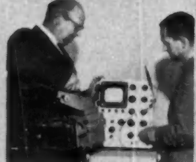


Typical hysteresis loops (multiple exposure of varying amplitudes).

Damped sine wave (multiple exposure using all 5 detent positions).

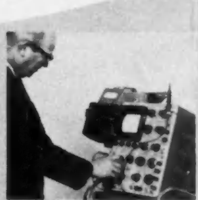
Family of characteristic curves (for NPN transistor).

...like this



One-hand portability

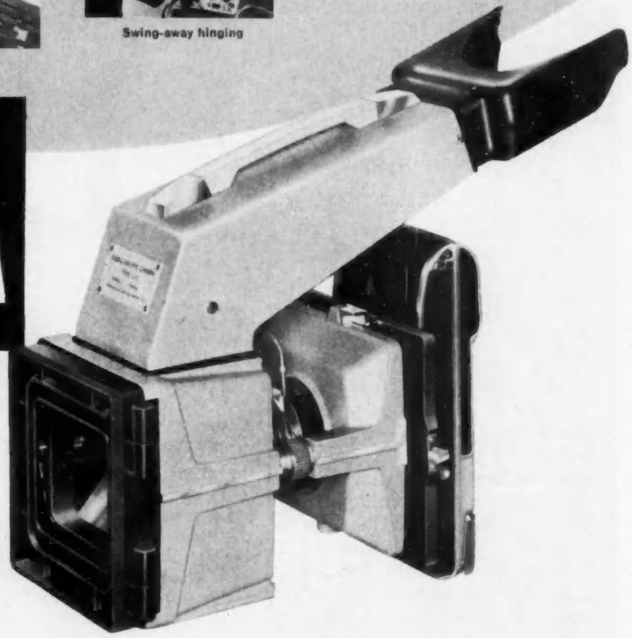
Lift-on mounting



Swing-away hinging

Comfortable viewing—with or without glasses

...only *with this*
C-12 CAMERA



The C-12 Camera combines flexibility with simplicity. It offers you new convenience in undistorted viewing and direct recording of oscilloscope traces.

Here's why:

You can use Polaroid* or any conventional film.

You can use the unique sliding back, adjustable to horizontal or vertical. On this sliding back, you can interchange the parfocal, film-holding backs, lock them securely in 5 detent positions, also rotate them thru 90° increments (with the long axis of the film horizontal or vertical).

You can choose from 8 easily-interchangeable lenses — in varying object-to-image ratios and maximum aperture to f/1.5. The lenses are housed in uniform, pre-focused, calibrated mounts with keyed threads — so the shutter-speed and diaphragm-opening controls always appear at the same accessible position on the camera.

For more information about these and other features of the new C-12 Camera . . . and the many accessories designed for specialized applications . . . call your Tektronix Field Engineer.

C-12 CAMERA **$500**

Includes: f/1.9 Lens (with 1:0.9 object-to-image ratio) complete with cable release, Focusing Back, Polaroid Back, and Minute Timer.*

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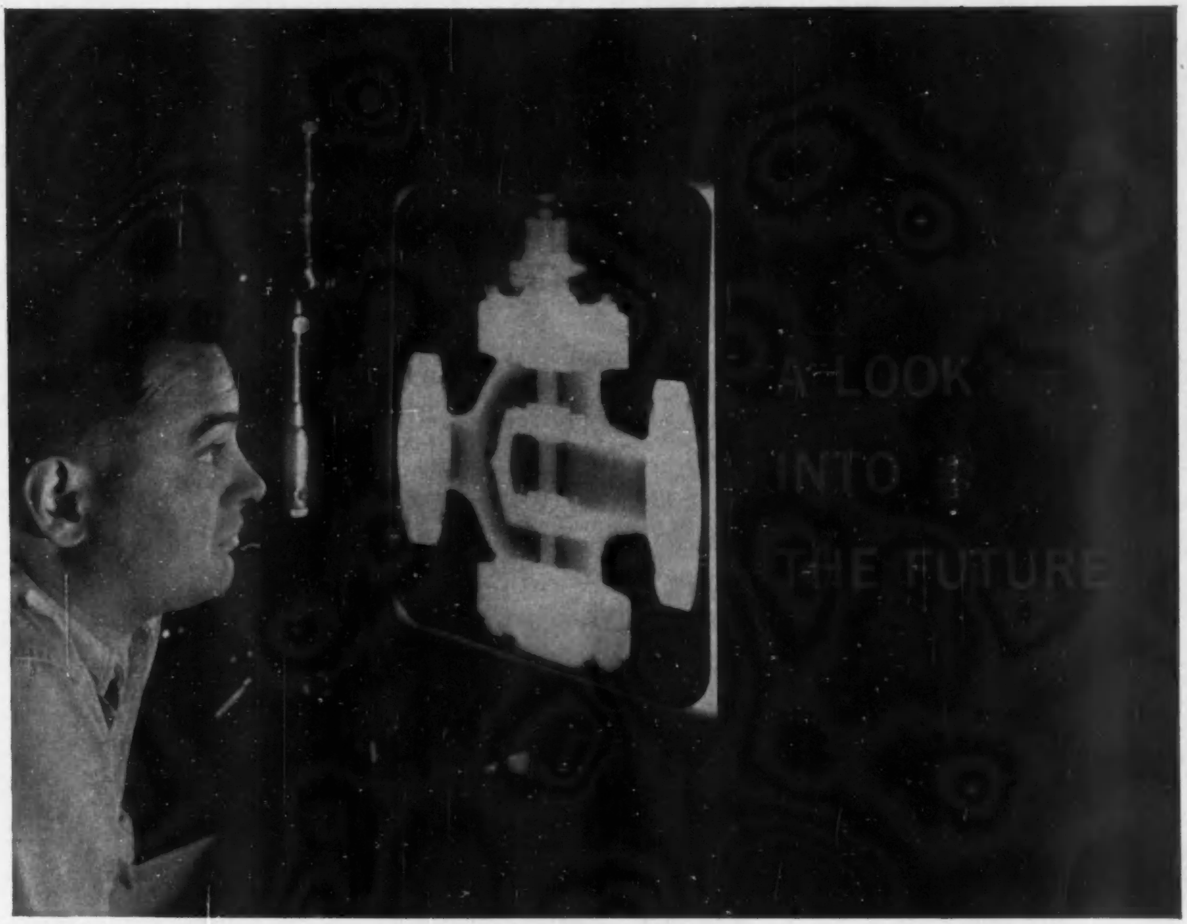
TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics, Portland, Oregon • Seattle, Washington. Tektronix is represented in twenty overseas countries by qualified engineering organizations.

In Europe please write Tektronix Inc., Victoria Ave., St. Sampsons, Guernsey C.I., for the address of the Tektronix Representative in your country.



Neither stargazer nor mystic, this K & M technician can nevertheless see into the future. His crystal ball is a small mass of radioactive Iridium; his fortune-telling cards, gamma-ray pictures of critical valve assemblies. With these pictures he searches out the kind of subtle flaws and tiny imperfections that could become trouble spots at some future time. And so he is able to predict and prevent in-service failures and malfunctions.

Radiographic inspection is just one way in which K & M works to insure a long and healthy service life for its products. K & M's in-plant quality control facilities range from a contour comparator, for precision checking of small parts, to a 4000-gpm flow test loop, where sample valves from the production line are tested for on-stream performance. Micrometer and calipers play an important part, too, for each K & M valve is subjected to more than eight hundred dimension check-outs before it reaches the shipping crate. It's either perfect, or "no go."

K & M's meticulous standards of quality control are neither myth nor magic . . . just good business — for us, and for you.

For a more detailed view of our plant and production practices, send for the well-illustrated, informative brochure, "This Is K & M."

K&M

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Oldest Pressure and Level Control Valve Manufacturer
64 Genung Street, Middletown, New York

D.A. 1002

The newest Mincom magnetic tape instrumentation recorder/reproducer, to be announced in detail next month, answers the need for better performance in the intermediate frequencies. Covering bandwidths from 200 cps to 300 kc at 60 ips with improved dynamic range, it fills the gap between Mincom's Model C-100 (125 kc-60 ips) and the Model CM-100 (1 mc-120 ips). The new model also is extremely versatile, offering both FM and Direct recording/reproducing. One-rack compactness, all-transistorized electronics. Wait and see more of this new system's extra capabilities.

3M COMPANY ... WHERE RESEARCH IS THE KEY TO TOMORROW

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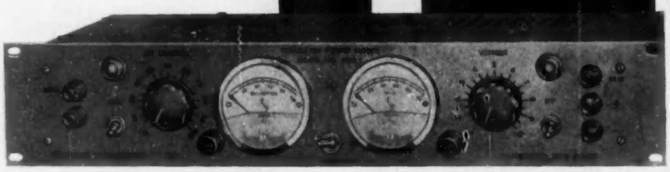
the 42 most popular ®REGATRON POWER SUPPLIES are programmable



MODEL 212A $129 WITHOUT METERS

0.1% REGULATION MODELS	DC OUTPUT VOLTS	DC OUTPUT MA	0.01% REGULATION MODELS
220A	0-50	0-500	220AK
213A	0-50	0-1000	213AK
215A	0-50	0-3000	215AK
225A	0-75	0-2000	225AK
212A[1]	0-100	0-100	212AK[1]
2-212A[1,3]	0-100X2	0-100X2	2-212AK[1,3]
224A[1]	0-100	0-200	224AK[1]
221A	0-100	0-500	221AK
214A	0-100	0-1000	214AK
226A	0-100	0-2000	226AK
218A	0-100	0-3000	218AK
229A	0-150	0-300	229AK
228A	0-150	0-1000	228AK
230A	0-200	0-1000	230AK
231A[2]	0-300	0-100	231AK[2]
232A[2]	0-300	0-200	232AK[2]
233A[2]	0-300	0-300	233AK[2]
234A	0-300	0-500	234AK
237A	0-300	0-1000	237AK
236A[2]	0-600	0-200	236AK[2]
235A	0-600	0-500	235AK

[1] Has modulation input.
[2] Has additional 0-150 V DC output and 6.3 V AC CT output.
[3] Equivalent to two Model 212A's.

Why programmable? Because Regatron Programmable Power Supplies give the design engineer an extra margin of versatility. For example, in automatic test work, the programmable feature reduces control circuitry. In critical laboratory application, the programmable feature permits near-perfect reproducibility of test voltages.

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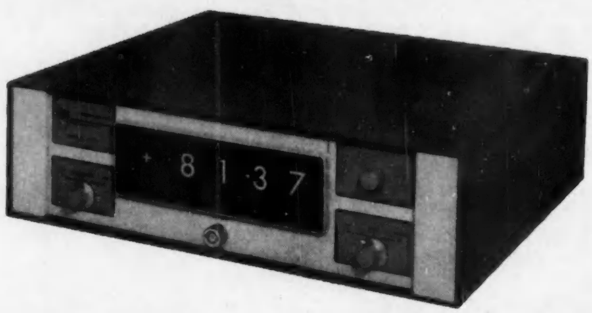

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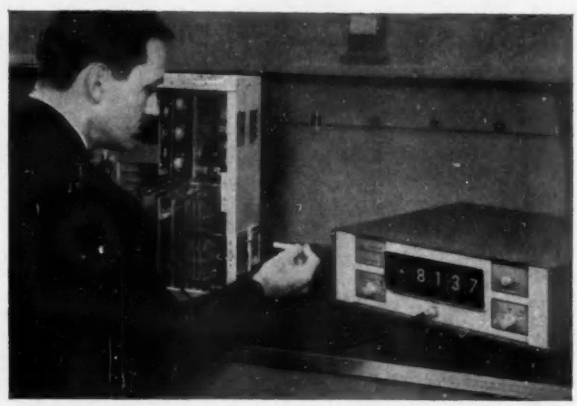

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Growing Market in Europe And How to Sell it—Part II

As Europe gears up for its greatest production expansion since the industrial revolution, the demand for instrumentation and control equipment has reached an all-time high. In countries where the control industry is highly developed, last year's growth was startling: in Germany, instrument and control production jumped 30 percent and couldn't meet the demand; in France, it rose 15 percent; in Britain, it increased 10 percent and may grow another 20 percent this year (see CtE, January, 1961, p. 57).

The growth story is even more impressive in those countries in which the instrumentation and control industry had been backward previously. In Italy, for example, until recently (as late as 1959) laboring forces violently opposed the application of any automatic device as an evil that would bring misery to an unemployment riddled country. Today, Italy's industrial structure is booming so hard there is a severe labor shortage in the heavily industrial northern part of the country. Manufacturing companies have been forced to shape their expansion plans around the normally agricultural south and are avidly searching for the newest techniques in instrumentation and control to minimize the size of the labor forces.

From Milan, the industrial center of the north, McGraw-Hill Newsman Gene DeRaimondo described what's happening in this surprising turnabout.

Italian industry is enjoying prosperity to an extent never anticipated. Typical of how this is affecting the instrument and control industry is what is happening to electronic instrumentation. Says Giorgio Quazza, head of CEA-Perego's control equipment research center, "The expansion of electronic instrumentation in Italy and Europe has gone beyond our wildest expectations. Although Italian companies were late starters, we have now caught up in equipment development."

In process control, although almost 80 percent of instrumentation has been pneumatic, a change-over from pneumatics to electric or electronics is under way. Enea Torrielli, chief of the mechanical department of Agip Nucleare, underlines the switch. He says, "I think the transformation (from pneumatic to electric and electrohydraulic controls) will be complete within five years. Pneumatic controls have reached their maximum."

Italy is still primarily an importer of instruments. Almost 60 percent of the instruments used in the country's process control industry are made elsewhere. In 1960, such imports totaled $15 million, a 30 percent increase over 1959. But domestic production of the same kind of devices is growing just as fast; it also increased 30 percent last year. Major Italian producers include Tieghi of Milan (ownership divided so that 49 percent is Italian and 51 percent English), Guardigli, Regulator of Milan (partly owned by General Precision Equipment), Spriano-Bosco-Sis, Thermochimk (which produces under license to Hagan Controls), and SAE (producing under license to the British company Electro-flo).

Despite the imports, Italian buyers are heavily prejudiced in favor of equipment built in Italy, a buying characteristic to be watched in the future. CEA-Perego's Quazza said, "Today it is almost impossible to sell foreign-made electronic drives or small systems in Italy, except if they are part of a whole plant which has been imported." Confirming this is the fact that 95 percent of the industrial controls bought last year were domestic-made. The major suppliers: CEA-Perego, which specializes in controls for electric utility plants; Prodest of Milan, whose specialty is numerical control for machine tools; Ghisalba of Turin, machine tool control maker; and CGE, a General Electric subsidiary that makes electronic drives for steel mills and paper mills. Sales ran about $5 million last year, with CGE accounting for about $1.5 million and CEA-Perego for $1 million.

The purchase of computer equipment is one area that does not yet follow the "Buy Italian" theme. There are no Italian manufacturers of general purpose analog computers; the U. S. company Electronic Associates supplied almost 90 percent of those in use in Italy.

U. S. companies have supplied almost 95 percent of the digital computers installed in Italy; German companies have sold the rest. Last year, Olivetti introduced the first Italian digital machine, the Elea 9003, and the company is said to be planning additional equipment. CEA-Perego is making data loggers and has developed a digital computer for process control, although this machine is not yet commercially available.

Behind this growing industry are ten outstanding men. Their names, organization, and specialties:

CARLO CALOSI ——— Managing Director; Selenia; electronic fire control

PAOLO MARSILI ——— Professor; University of Geneva; mercury arc rectifiers

CARLO COSTADONI — Technical Director; CGE; mercury arc rectifiers

GIORGIO QUAZZA ——— Head, Control Equipment Research Center; CEA-Perego; servo systems

ENEA TORRIELLI ——— Chief, Mechanical Department; Agip Nucleare; instrumentation

MARIO TCHOU ——— Head, Research Center; Olivetti; computers

EMILIO GATTI ——— Head, Research Center; CISE; nuclear instrumentation and control

EZIA VOLTA ——— Professor; University of Genoa; process control

LUIGI BERNARDINI ——— CEA-Perego; digital controls

SERGIO BARABASHI — Head, Laboratory; CNRN; servomechanisms

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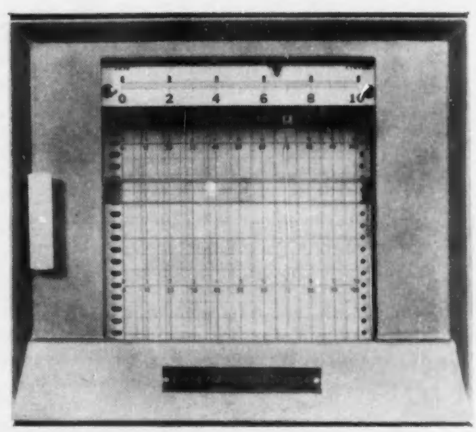

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Considering what's ahead for Italian control, these men see these developments that will bring Italy closer to the present state of the art in the U. S.: wider use of semiconductors in all electronic control equipment; application of silicon controlled rectifiers for switching; widespread acceptance of numerical control; more static controls; introduction of digital control systems; and programmed controls replacing manual operations.

Another country that has been watching the boom in Europe closely is Switzerland, traditionally a supplier of hardware rather than raw materials. In Switzerland, the story of what is happening shows up in the country's export figures:

	1960	*1959*
	(millions of dollars)	
Process instruments and control.	$0.06	$0.15
Electrical instruments and control	10.0	8.9
Physical instruments	4.0	3.2
Precision mechanical instruments	8.5	8.0

From these data, it is obvious that Swiss companies have concentrated on controls for electrical and mechanical machines rather than process control for chemical or petroleum plants. For 1961, Swiss manufacturers expect a 10 to 20 percent increase in exports of their lines of instrumentation and control.

From Zurich, McGraw-Hill Newsman Raymond Shah sent this description of the Swiss instrument and control industry:

Domestic manufacturers dominate the Swiss instrument and control industry. The leaders, and their specialties:

Industrial Control: Brown Boveri; Fr. Sauter; Landis & Gyr; Contraves; Schindler; and Secheron.

Instrumentation: Landis & Gyr; Trub Tauber; Bodeco; and Jaquet.

Computers: Guttinger, Contraves, and Amsler.

About 15 percent of the total control business is being accounted for by U. S. companies through Swiss subsidiaries. Honeywell's Zurich subsidiary is a leader, as are IBM's Extension Suisse and Remington Rand's Zurich company in the computer business. U. S. influence is also felt through Swiss companies that are agents for U. S. companies, such Swiss organizations as Seyffer, Baerlocher, and Telion. One Swiss company, Omni Ray of Zurich, recently opened a computer center supplied with equipment from the U. S., but the company is building some of the peripheral equipment locally.

Professor Eduard Gerecke, on the faculty of the Swiss Federal Institute of Technology and president of the Swiss Automatic Control Society, predicts that instrument and control activity will continue to expand at a great rate in his country. He feels the current trend with the most momentum is the replacement of analog with digital techniques.

Proof that U.S. companies have been participating in the boom in Europe comes from Washington, where export statistics show, for most kinds of equipment, that our overseas instrument and control business is growing. Here are some typical figures for 1958, 1959, and 1960. Note that the figures for 1960 are for only nine months, while the others are for 12 months.

	1958	*1959*	*1960**
	(millions of dollars)		
Pilot circuit devices	$4.5	$5.4	$4.6
Industrial motor control	2.0	2.6	2.1
Industrial process indicating, recording, controlling instruments	46.0	46.3	40.1
Indicating, controlling and recording instruments	16.1	19.4	15.8
Office, accounting, and computing machines	4.7	4.0	3.8

* *First nine months*

As the export figures show, it is still possible to sell American-made products in Europe. The highest degrees of success are being reported by those who make a product that can be made in large volume production, that contains rare or sophisticated materials, or that has a unique design with performance superior to competitive products. U.S. instruments and controls, for the most part, enter the European market with a price disadvantage which can sometimes be offset by application engineering or service not offered by European makers. Short delivery times have also helped U.S. makers, since most European suppliers are oversold.

To sell those products that are standardized with no unique features, U.S. companies are likely to find the answer to the European market in European plants or subsidiaries. These have pitfalls as well as advantages.

Probably the most important nontechnical factor is the effect of nationalism. This works both ways. In more and more countries, the flames of nationalism are prejudicing buyers against products not made in the country. The buyers seem to like it better if a foreign design is built in their country. Still, some countries have laws barring majority ownership by foreign citizens or prohibit the conversion of profits to another currency if a majority of the company is not owned by nationals. And the flood of nationalism may wash out foreign investment completely, as it has done in Cuba.

With such pitfalls balanced against a growing potential, the European market offers a tempting challenge for U.S. control makers.

Control
ENGINEERING

FEBRUARY 1961

Bugs and humbugs

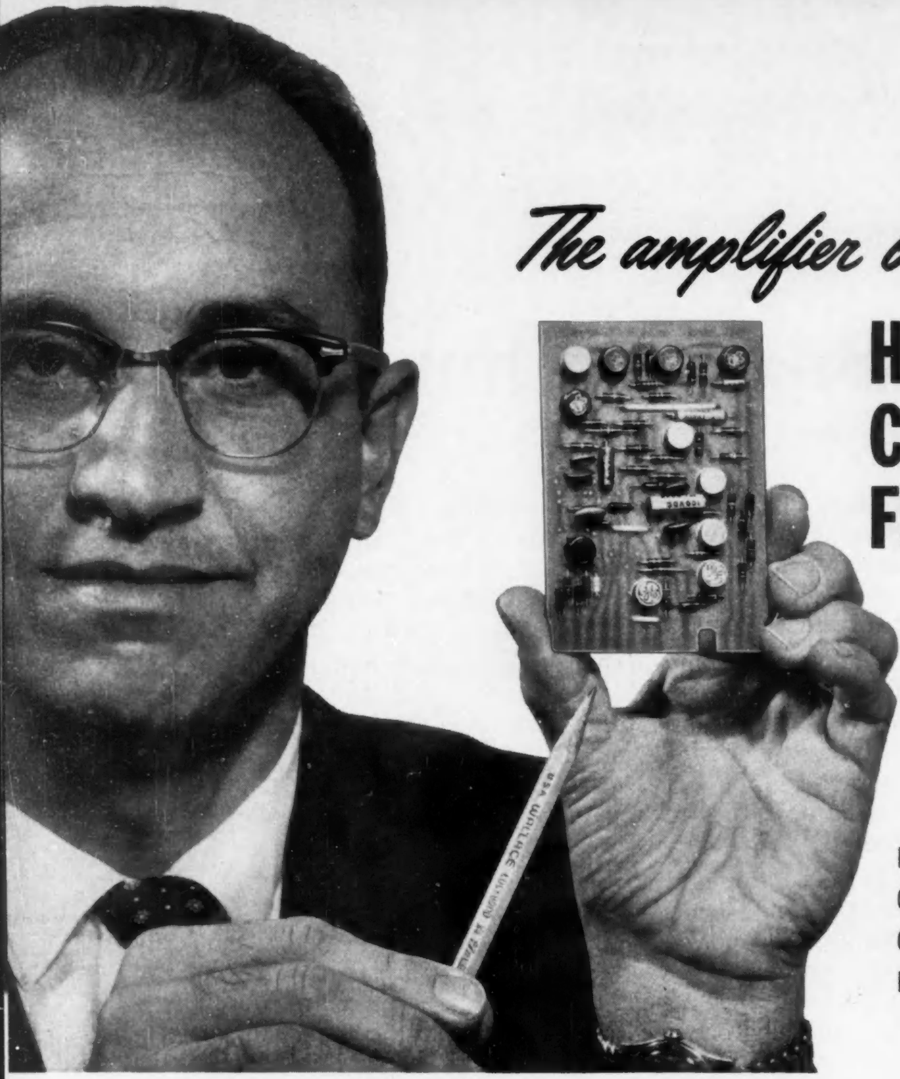
Two days after Christmas *The Wall Street Journal* published a front-page story headed "Bugs in Automation". The story presented a welter of short case histories demonstrating that business, industry, and defense managements have become disenchanted with automation. We quote a summary paragraph:

> *"Among the common company complaints: Equipment and installation costs often run higher than expected; (computer) manufacturers sometimes oversell the blessings of their products; equipment complexity causes frequent and expensive breakdown; and the new apparatus in some cases may turn out to be altogether too elaborate for the job it has to do, thus making the required investment unnecessarily large."*

As in the controversial book entitled **The Crisis We Face—Automation and the Cold War** (see "Rebuttal by the Military," CONTROL ENGINEERING, Dec. '60, pp. 77-83), the story puts the finger on overcomplexity as the basic cause of the fall of automation from darling to devil. The story follows the lately popular bent of technical writers to attract readership by publishing one-sided and often frivolous examinations of technological advance. We deplore the bent because it confuses the uninformed. Nevertheless, while mostly humbug, the story does reveal authentically the disaster that management invites when it blindly jumps on any technological bandwagon. The complaints cited are real because of over-eager reaching for a panacea—automation.

Let automation lie, diffused and disenchanting, not because of overcomplexity, but because of overzealous and unrealistic application. Control, on the other hand, will enjoy a healthy expansion because the control field will accept no substitute for careful engineering of automatic systems. We cannot duck the fact that the machines, processes, defense missions, and business operations to which control is applied are becoming increasingly complex. Nor can we escape the rapid trend of control systems to master larger and larger portions of operations. The result will be more complex control systems, for which there are no easy cure-alls. Don't look for panaceas; they breed bugs.

V. E. Vannah



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Originally developed, used, and tested in critical missile applications, the amplifier is available as an off-the-shelf item at regular stock prices. This amplifier has found acceptance wherever reliability and minimum size and volume are important considerations. The standard version weighs 3 ounces and possesses external dimensions of 3¾ inches long by 2¼ inches wide by ½ inch thick. A hermetically sealed version which occupies only 2 cubic inches is also available.

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analyze nonlinear controls with SATURATION FUNCTIONS

THE GIST: The saturation function technique is a powerful method for analyzing nonlinear control systems, especially those containing such strongly nonlinear elements as relays and dead time. A particular advantage of this technique is that it yields quantitative information about the amplitude, period, and waveform of the limit cycle directly in the time domain.

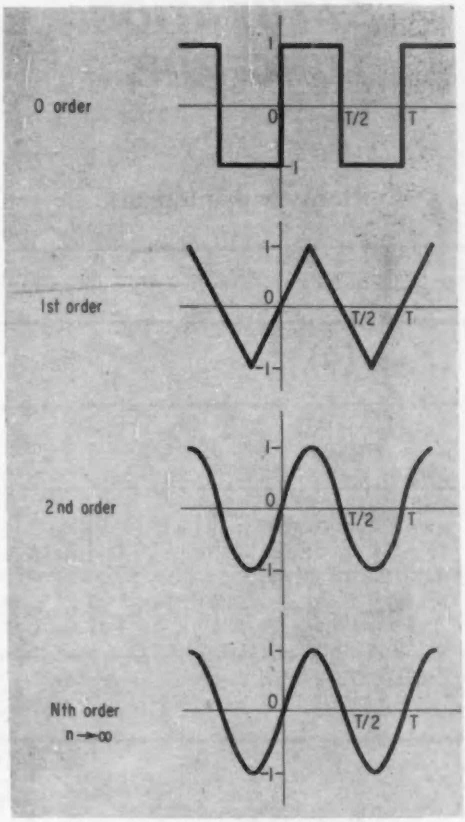


FIG. 1. Saturation functions occurring in common nonlinear systems.

SHUNJI MANABE
Mitsubishi Electric Manufacturing Co.,
Japan

The saturation-function technique is a literal method of nonlinear analysis, not graphical like the phase plane and describing function techniques. Simply stated, the present method keeps track of a waveform, here called a saturation function, as it changes by going from the starting point through each linear and nonlinear element in the closed control loop. The original-waveform equation and the propagated-waveform equation returning to starting point are set equal to each other (since the two equations must represent the same waveform) and the problem is solved for the period and amplitude of the limit cycle. Then the waveform at the output (that of the limit cycle) can be determined.

Saturation functions and their properties

Figure 1 shows some saturation functions of order 0, 1, 2, and infinity as might occur in common nonlinear control systems. An nth order saturation function is defined as:

$$a_n\left(\frac{t}{T}\right) = \frac{\int_0^t a_{n-1}\left(\frac{1}{4} - \frac{t}{T}\right)dt}{\int_0^{T/4} a_{n-1}\left(\frac{1}{4} - \frac{t}{T}\right)dt}; \quad 0 \leq t \leq T/4 \qquad (1)$$

where T is the period. Saturation functions are periodic functions, and thus in the undefined interval of the period the waveform repeats the defined "quadrant' in a manner similar to that of a sine wave.

Starting with a 0-order saturation function—a square wave with unity amplitude and T period—higher-order functions can be obtained from Equation 1. They are listed in Table I, and their values

WHAT'S NEEDED TO USE SATURATION FUNCTIONS

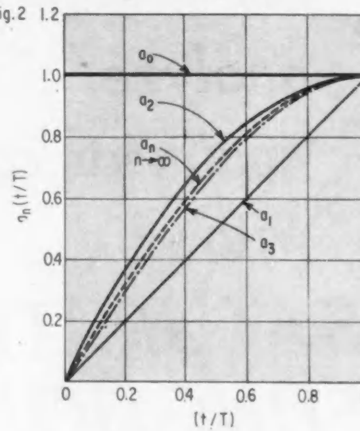
1. Definitions and Integrals

TABLE I

Entry	Function	Definition $0 \leq t \leq T/4$	Integral
1	$a_0\left(\frac{t}{T}\right)$	1	$\frac{T}{4}a_1\left(\frac{t}{T}-\frac{1}{4}\right)$
2	$a_1\left(\frac{t}{T}\right)$	$\frac{4t}{T}$	$\frac{T}{8}a_2\left(\frac{t}{T}-\frac{1}{4}\right)$
3	$a_2\left(\frac{t}{T}\right)$	$\frac{8t}{T}\left[1-\frac{1}{2}\left(\frac{4t}{T}\right)\right]$	$\frac{T}{6}a_3\left(\frac{t}{T}-\frac{1}{4}\right)$
4	$a_3\left(\frac{t}{T}\right)$	$\frac{6t}{T}\left[1-\frac{1}{3}\left(\frac{4t^2}{T}\right)\right]$	$\frac{5T}{32}a_4\left(\frac{t}{T}-\frac{1}{4}\right)$
5	$a\infty\left(\frac{t}{T}\right)$	$\sin\frac{2\pi}{T}t$	$\frac{T}{2\pi}\sin 2\pi\left(\frac{t}{T}-\frac{1}{4}\right)$

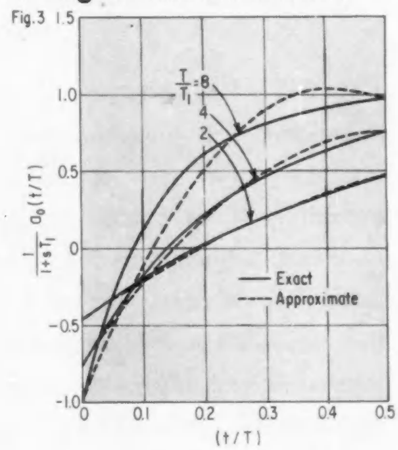
2. Limit Cycle Waveforms

Fig. 2



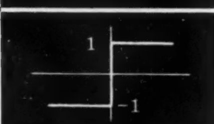
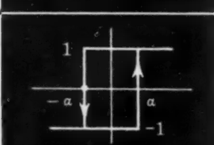
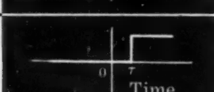
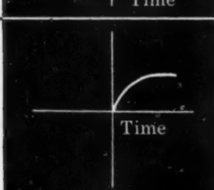
4. Lag Saturation Function

Fig. 3



3. Input-Output Characteristics

TABLE II

Control element	Input saturation function	Nonlinearity	Operation	Output saturation function	Comments	Equation
Bang-bang H	$ka_n\left(\frac{t}{T}\right)$		$H\left[ka_n\left(\frac{t}{T}\right)\right]$	$a_0\left(\frac{t}{T}\right)$ *if* $k>0$ $-a_0\left(\frac{t}{T}\right)$ *if* $k<0$	Output is square wave regardless of shape of input saturation function.	9
Hysteresis (backlash) H_a	$ka_n\left(\frac{t}{T}\right)$		$H_a\left[ka_n\left(\frac{t}{T}\right)\right]$	$a_0\left[\left(\frac{t}{T}\right)-\phi\right]$ where $kA_n(\phi)=a$	Output is square wave, but delayed by f(a), regardless of shape of input waveform.	10
Dead time $e^{-\tau s}$	$ka_n\left(\frac{t}{T}\right)$		$e^{-\tau s}\left[ka_n\left(\frac{t}{T}\right)\right]$	$a_n\left[\left(\frac{t}{T}\right)-\frac{\tau}{T}\right]$	Output is original saturation function but delayed by τ/T.	11
Time lag $\frac{1}{1+sT_1}$	$a_0\left(\frac{t}{T}\right)$		$\frac{1}{1+sT_1}\left[a_0\left(\frac{t}{T}\right)\right]$	$\cong \tanh\frac{T}{4T_1}$ $\times\left[\tanh\frac{T}{8T_1}a_2\left(\frac{t}{T}\right)\right.$ $\left.+a_1\left(\frac{t}{T}-\frac{1}{4}\right)\right]$	For goodness of approximation, see Figure 3.	12

as a function of t/T are plotted in Figure 2.

Due to periodicity and symmetry, the following relationships hold for any saturation function:

$$a_n\left(\frac{t}{T} \pm \frac{1}{2}\right) = -a_n\left(\frac{t}{T}\right) \tag{2}$$

$$a_n\left(\frac{t}{T} \pm m\right) = a_n\left(\frac{t}{T}\right), \text{ where } m \text{ is any integer} \tag{3}$$

$$a_n\left(\frac{1}{2} - \frac{t}{T}\right) = a_n\left(\frac{t}{T}\right) \tag{4}$$

$$a_n\left(-\frac{t}{T}\right) = -a_n\left(\frac{t}{T}\right) \tag{5}$$

Furthermore, the definite integral of a saturation function is:

$$\int_0^t a_n\left(\frac{x}{t}\right)dx = A_n\left(\frac{1}{4}\right)\left[1 + a_{n+1}\left(\frac{t}{T} - \frac{1}{4}\right)\right] \tag{6}$$

and the indefinite integral is:

$$\int a_n\left(\frac{t}{T}\right)dt = A_n\left(\frac{1}{4}\right)a_{n+1}\left(\frac{t}{T} - \frac{1}{4}\right) \tag{7}$$

$$\text{where } A_n\left(\frac{1}{4}\right) = \int_0^{T/4} a_n\left(\frac{x}{T}\right)dx \tag{8}$$

The indefinite integrals of some saturation functions are listed in Table I.

Operation on saturation functions by basic control elements

As is well known, a control system may be subdivided into blocks, each block or element representing a distinct part of the controlled process or a particular control component. Such elements may exhibit linear or nonlinear characteristics. Therefore, the output saturation function for any control element depends not only on the input saturation function but also on the specific characteristics of the element under consideration.

Table II displays output saturation functions derived from elements commonly found in nonlinear control loops, as a function of the input saturation function. Consider Entry 1 in Table II, for example. Here an input saturation function of any order going through a bang-bang nonlinearity like that obtained from an "ideal" relay (no dead zone, no hysteresis) will become a 0-order saturation function (a square wave) of unity amplitude.

Determining the limit cycle for typical nonlinear control systems

The foregoing definitions, relationships, and properties will now be applied to three different control systems to determine the period, amplitude, and waveform of their output limit cycles.

EXAMPLE 1. *Control system with bang-bang saturation, dead time, and integration*

The block diagram for this nonlinear control system is shown in Figure 4. The problem is to determine the system's limit cycle at the output point C in terms of period, amplitude, and waveform. Since only the limit cycle is of interest, input e_i can be assumed to be zero. If a limit cycle exists, the waveform at point A must be a saturation function of zero order, $a_0(t/T)$, regardless of the limit cycle's waveform at point D, $a_n(t/T)$. (Refer to Equation 9 in Table II.) The assumed period T will be calculated later.

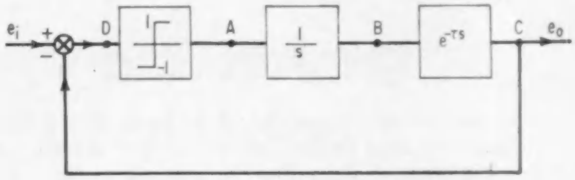


FIG. 4. Control system with bang-bang saturation, dead time, and integration.

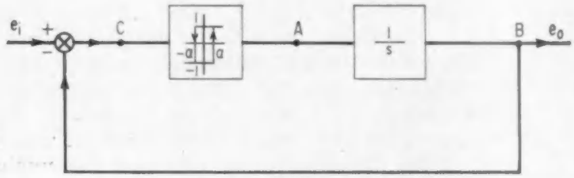


FIG. 5. Control system with integration and saturation containing hysteresis.

The procedure is to trace the saturation function at point A through all elements in the closed loop back to point A.

$$\textbf{Point A} \quad a_0\left(\frac{t}{T}\right). \tag{13}$$

$$\textbf{Point B} \quad \frac{1}{s}\, a_0\left(\frac{t}{T}\right) = \frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{1}{4}\right). \tag{14}$$

Since $1/s$ symbolizes integration, the integral of the 0-order saturation function is found from Table I, Entry 1.

$$\textbf{Point C} \quad e^{-\tau s}\frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{1}{4}\right) = \frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{1}{4} - \frac{\tau}{T}\right), \tag{15}$$

from Table II, Equation 11. Here the dead time might be the relay's contact closure delay after application of the input signal to the relay coil.

$$\textbf{Point D} \quad -\frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{1}{4} - \frac{\tau}{T}\right) = \frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{1}{4} - \frac{\tau}{T} - \frac{1}{2}\right), \tag{16}$$

from Equation 2.

$$\textbf{Point A} \quad H\left[\frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{\tau}{T} - \frac{3}{4}\right)\right] = a_0\left(\frac{t}{T} - \frac{3}{4} - \frac{\tau}{T}\right), \tag{17}$$

from Table II, Equation 9.

Since Equations 13 and 17 represent the same waveform, they must be related by Equation 3. Because of negative feedback, minus 1 is substituted for m in Equation 3. Therefore:

$$\frac{t}{T} - \frac{3}{4} - \frac{\tau}{T} = \frac{t}{T} - 1 \quad (18)$$

or

$$T = 4\tau \quad (19)$$

In other words, the period of the limit cycle is four times the dead time.

Equation 15 represents the system's output. By substituting Equation 19 into Equation 15, the amplitude and waveform at C are determined:

$$e_0(t) = \tau a_1\left(\frac{t}{4\tau} - \frac{1}{2}\right) \quad (20)$$

Thus, for this control system the saturation function technique yields the exact period, amplitude, and waveform of the limit cycle at the output. By comparison, the describing-function technique would have yielded the same period $T/4\tau$, but the amplitude would have been $8\tau/\pi^2$—an error of about 20 percent when compared with τ in Equation 20.

EXAMPLE 2. Control system with integration and saturation containing hysteresis

The block diagram for this nonlinear control system is shown in Figure 5. Here:

$$\textbf{Point A} \quad a_0\left(\frac{t}{T}\right) \quad (21)$$

$$\textbf{Point B} \quad \frac{1}{s}\, a_0\left(\frac{t}{T}\right) = \frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{1}{4}\right) \quad (22)$$

$$\textbf{Point C} \quad \frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{1}{4}\right) = \frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{3}{4}\right) \quad (23)$$

$$\textbf{Point A} \quad H_\alpha\left[\frac{T}{4}\, a_1\left(\frac{t}{T} - \frac{3}{4}\right)\right] = a_0\left(\frac{t}{T} - \frac{3}{4} - \phi\right), \quad (24)$$

from Table II, Equation 10, where:

$$\frac{T}{4}\, a_1(\phi) = \alpha \text{ or by Table I, Entry 2}$$

$$\frac{T}{4}\, 4\phi = \alpha \qquad \text{or} \qquad \phi = \frac{\alpha}{T} \quad (25)$$

From Equations 21 and 24

$$\frac{t}{T} - 1 = \frac{t}{T} - \frac{3}{4} - \phi \qquad \text{or} \qquad \phi = \frac{1}{4}$$

Then, from Equation 25:

$$T = 4\alpha \quad (26)$$

In other words, the period of the limit cycle is four times the half width of the hysteresis. The output waveform at point B, from Equation 22 is

$$e_0(t) = \alpha\, a_1\left(\frac{t}{4\alpha} - \frac{1}{4}\right) \quad (27)$$

Here, the amplitude is α and the output has a triangular waveform. For the same system, the describing-function technique yields the same amplitude but a period 4.93α rather than the exact 4α.

EXAMPLE 3. Control system with bang-bang saturation and rate feedback

The block diagram for this saturated servomechanism is shown in Figure 6. Although this is a simplified system, many position servos can be reduced to this form in the high frequency range where the limit cycle takes place. Analysis gives:

$$e_0(t) = \frac{1}{J}\,\frac{T^2}{32}\, a_2\left(\frac{t}{T} - \frac{1}{2} - \frac{\tau}{T}\right) \quad (28)$$

where period T can be determined from Figure 7 provided the dead time τ and the rate time T_2 are known. Note in Equation 28 that the limit cycle's amplitude increases with the square of the period but the period decreases with an increase in rate time. For control systems like that in Figure 8 the period T can be obtained from Figure 9.

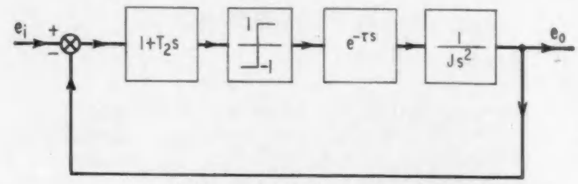


FIG. 6. Control system with bang-bang saturation, dead time, and rate feedback.

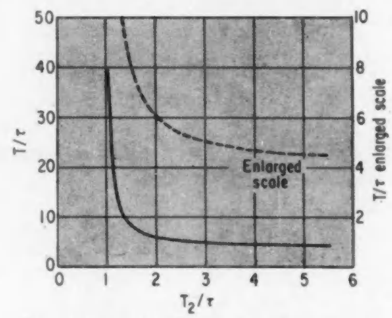


FIG. 7. Period of limit cycle for saturated servo with rate feedback and dead time.

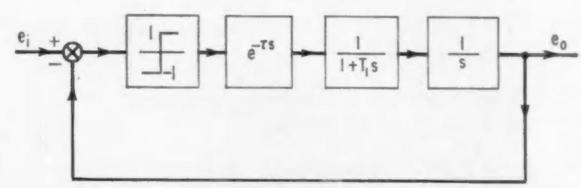


FIG. 8. Control system with bang-bang saturation, dead time, and velocity damping. For this saturated servo the period can be determined from Fig. 9.

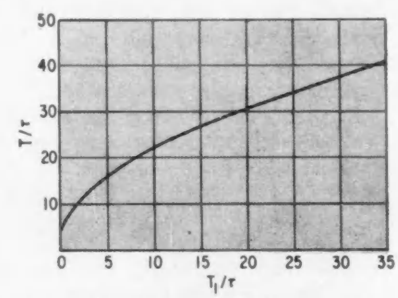


FIG. 9. Period of limit cycle for saturated servo with velocity damping and dead time.

Accurate Valve Sizing for Flashing Liquids

THE GIST: Of the various methods proposed for sizing control valves for flashing liquids, the one based on the downstream density of the liquid-vapor mixture seems the most accurate. With the aid of specially constructed curves and known inlet conditions, the instrument engineer can size a valve with a few simple calculations. Here the author explains the development and use of such curves, and presents usable charts covering six of the more common process fluids.

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The problem of sizing control valves for liquids that flash within the valve body itself has plagued instrument engineers for years. Past studies, while not in complete agreement, have produced some fairly accurate methods for use with flashing water.

Most authorities recognize that sizing valves for flashing liquids is a complex problem. The facilities and time required to test the multitude of common industrial fluids can be extremely costly.

A more recent investigation, however, has improved upon the best of these methods and can be readily applied to liquids other than water. One of the most valuable methods suggested to date is the so-called lower-density technique. This gets its name from the fact that the valve sizing correction is based on the lower density of the vapor-liquid mixture that exists after flashing occurs. The main advantages of this method are accuracy and the close correlation between theory and test results permitting its use with many other liquids.

Pressure-density curves

With a few minor assumptions, the equation for the specific gravity of flashed vapor-liquid mixture may be stated as follows:

$$G = \frac{G_L}{1 + 62.4\, G_L\, v_{G2}\,(h_1 - h_2)/h_{LG}} \qquad (1)$$

where G is the specific gravity of the flashed mixture, G_L the specific gravity of the liquid before flashing, v_{G2} the specific volume of the vapor formed (cu ft/lb mass), h_1 the enthalpy of the liquid before flashing (Btu/lb), h_2 the enthalpy of the liquid after flashing (Btu/lb), and h_{LG} the latent heat of vaporization (Btu/lb). A simplified derivation of this equation is presented in the box on page 90. Values needed to solve the equation can usually be found in thermodynamic charts or tables covering the liquid involved.

Assuming a fixed saturated inlet pressure P_{in} and solving Equation 1 for a sufficient number of outlet pressures yields values of G that can be plotted against outlet pressure as shown in Figure 1. With this curve and a planimeter, an extremely useful curve can now be plotted. The area under the curve in Figure 1, between the saturation pressure and any outlet pressure, is termed the usable density-pressure drop product. Successive integration of the areas between the saturation pressure and successively smaller outlet pressures produces a series of these ΔpG products which can then be plotted against their respective pressure drops. A curve through these points is a line of constant inlet pressure as shown in Figure 2.

Repeating the process for different saturated inlet pressures (different temperatures) produces a series of similar curves on these same coordinates.

Using the curves

The ease with which these curves can be used to size valves for flashing liquids can now be demonstrated. The one generally accepted formula for sizing valves for liquid service is written:

$$V = C_v \sqrt{\Delta p/G} \qquad (2)$$

where V is the flow rate (usually expressed as gpm),

(Text continued on page 90)

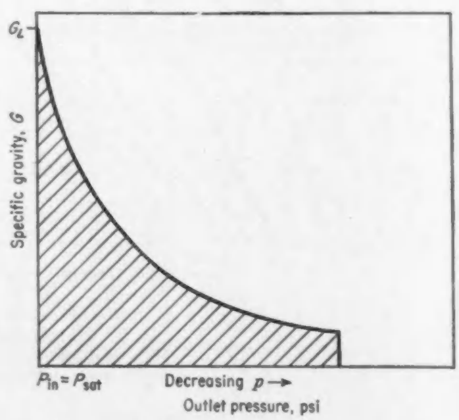
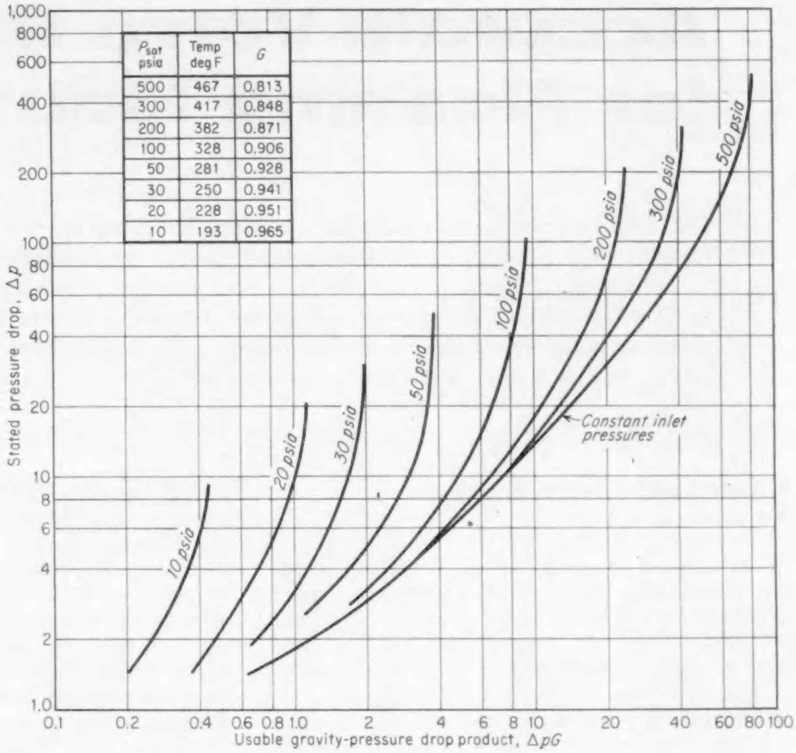


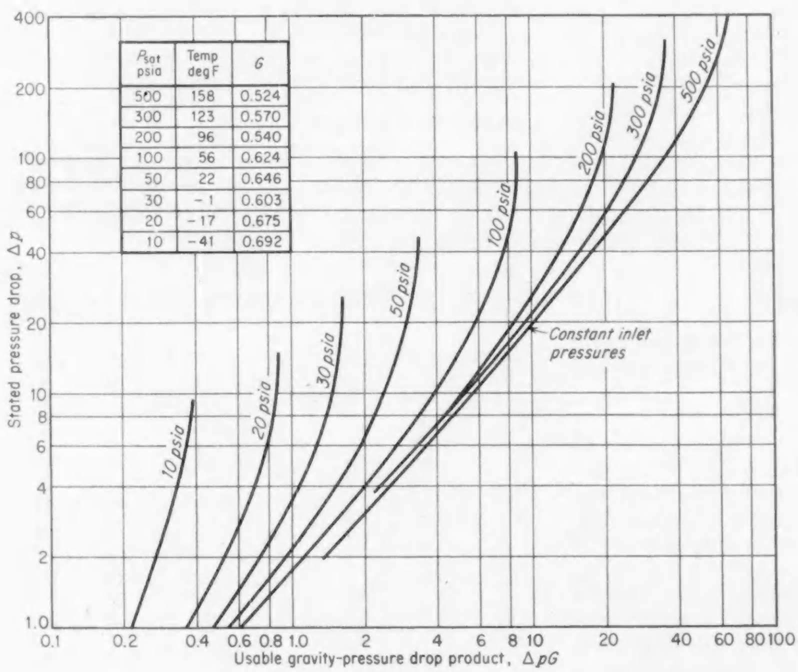
FIG. 1. Mixture density drops as outlet pressure is reduced.

NO. 1 SATURATED WATER



P_{sat} psia	Temp deg F	G
500	467	0.813
300	417	0.848
200	382	0.871
100	328	0.906
50	281	0.928
30	250	0.941
20	228	0.951
10	193	0.965

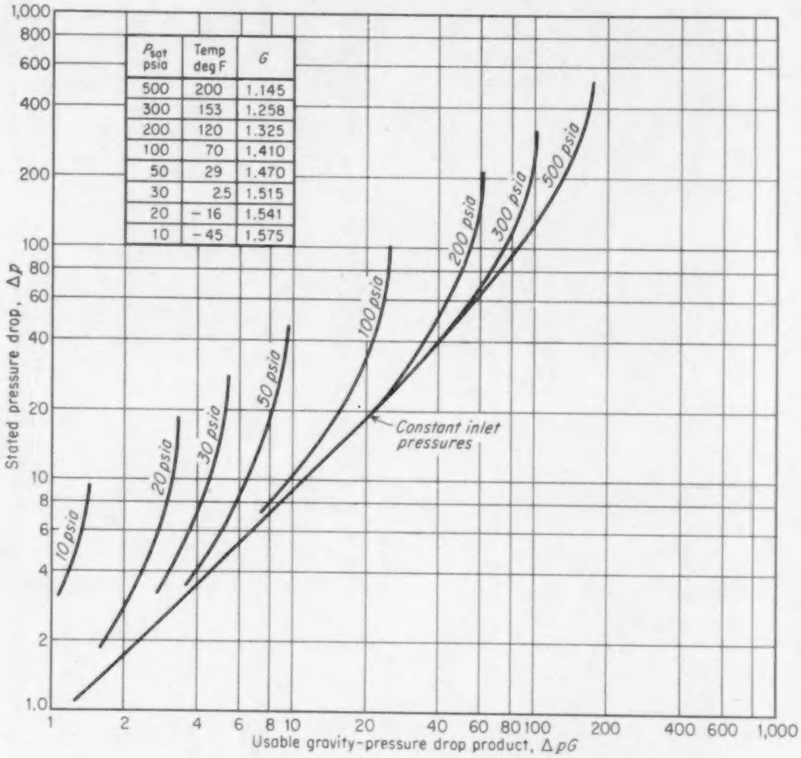
NO. 2 SATURATED AMMONIA



P_{sat} psia	Temp deg F	G
500	158	0.524
300	123	0.570
200	96	0.540
100	56	0.624
50	22	0.646
30	−1	0.603
20	−17	0.675
10	−41	0.692

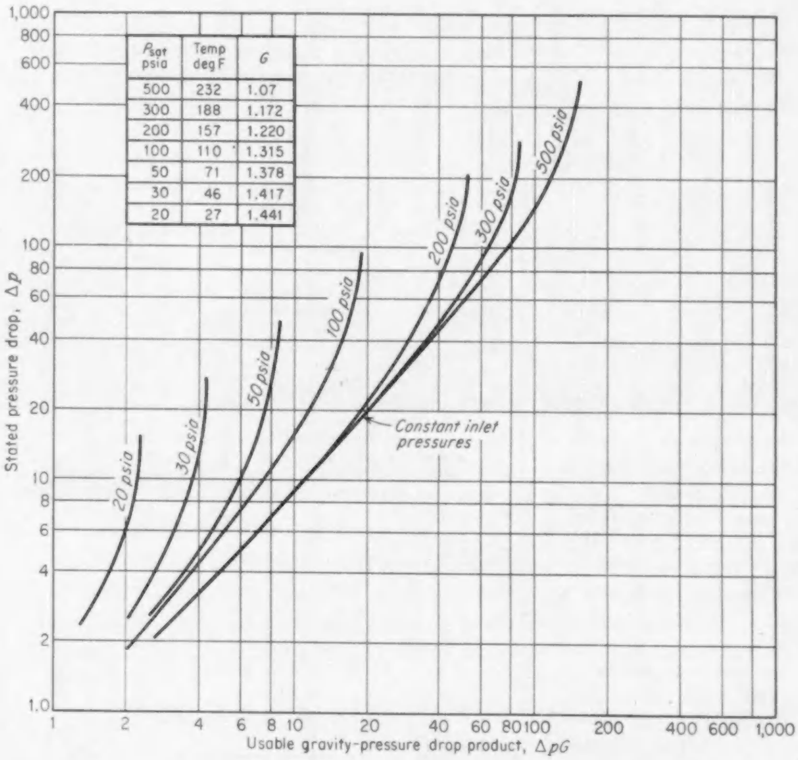
NOTE: The curves presented on these two pages cover four commonly used flashing fluids. Similar curves for nine additional fluids are available on request from the Conoflow Corporation. These other fluids include Freon 22, Dowtherm "A", methane, methylene chloride, normal butane, isobutane propane, propylene, and ethylene.

NO. 3 SATURATED CHLORINE



P_{sat} psia	Temp deg F	G
500	200	1.145
300	153	1.258
200	120	1.325
100	70	1.410
50	29	1.470
30	2.5	1.515
20	−16	1.541
10	−45	1.575

NO. 4 SATURATED SULPHUR-DIOXIDE



P_{sat} psia	Temp deg F	G
500	232	1.07
300	188	1.172
200	157	1.220
100	110	1.315
50	71	1.378
30	46	1.417
20	27	1.441

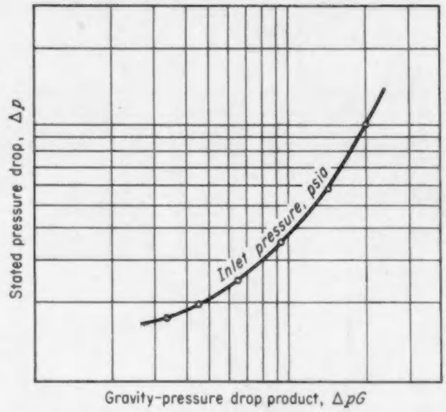


FIG. 2. The usable gravity-pressure drop product as a function of pressure drop across the valve for a single inlet pressure.

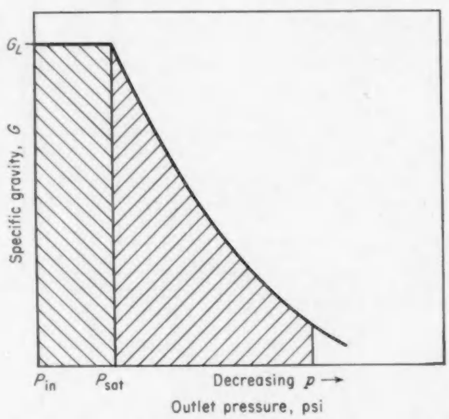


FIG. 3. Simple effect of starting with a supercooled liquid and dropping below the saturation pressure.

Δp the pressure drop across the valve, G the specific gravity of the flowing medium, and C_v the valve sizing coefficient. Multiplying both sides of this equation by the specific gravity G reduces it to:

$$GV = C_v\sqrt{\Delta pG} \tag{3}$$

The tremendous amount of calculation that went into the construction of the curves now pays off. The term ΔpG, for a given inlet pressure and pressure drop, can be read directly from the appropriate curve. If the desired flow is known, the proper valve coefficient can be calculated, or, if the valve coefficient is given, the allowable flow can be determined.

The curves on the following pages cover saturated water and five other common process fluids. The technique outlined above can, of course, be used to produce sets of curves for other flashing liquids.

Supercooled liquids

Where the inlet conditions are in the supercooled region but the pressure drop is still sufficient to produce an outlet pressure lower than the saturation pressure, the sizing equation is expanded as follows:

$$\begin{aligned} GV &= C_v\sqrt{G_L(P_{in} - P_{sat})} + C_v\sqrt{\Delta pG} \\ &= C_v\sqrt{G_L(P_{in} - P_{sat}) + \Delta pG} \end{aligned} \tag{4}$$

Figure 3 shows how the new term in this equation is represented on a gravity-pressure curve as the area of the rectangle to the left of the saturation pressure.

Typical problem

As an illustration of the method, consider the curves for saturated water and suppose a situation in which the inlet pressure was 100 psia and the temperature was 328 deg F, corresponding to saturation conditions. What will be the flow rate through a valve whose coefficient is 57 if the pressure drop within the valve is 6 psi? Chart 1 shows that at these conditions, ΔpG is 3.5. Substituting the known values in Equation 3,

$$GV = 57\sqrt{3.5} = 57 \times 1.87 = 106.7 \text{ gpm water at 60 deg F}$$

To get this in terms of gallons per minute of the actual liquid flowing, it is necessary to divide the result by the lower specific gravity G, which for water at 328 deg F equals 0.906. Thus,

$$V = 106.7/0.906 = 117.5 \text{ gpm}$$

Under actual test, using the same valve and inlet conditions, a flow of 120 gpm was obtained. This and similar examples illustrate the close correlation between calculated and test results.

It should be noted that limitations as to pressure ranges, nature of the liquids involved, and other factors certainly could affect the accuracy of this method, but experience of the past several years indicates that valves sized according to this technique have been found entirely suitable. The method is not perfect but is suggested as a rather reasonable and simple approach to a complex problem.

WHERE EQUATION 1 CAME FROM.

Based on a steady flow of one cubic foot of saturated liquid through a valve, the specific gravity of the resulting vapor liquid mixture can be calculated as follows:

Letting

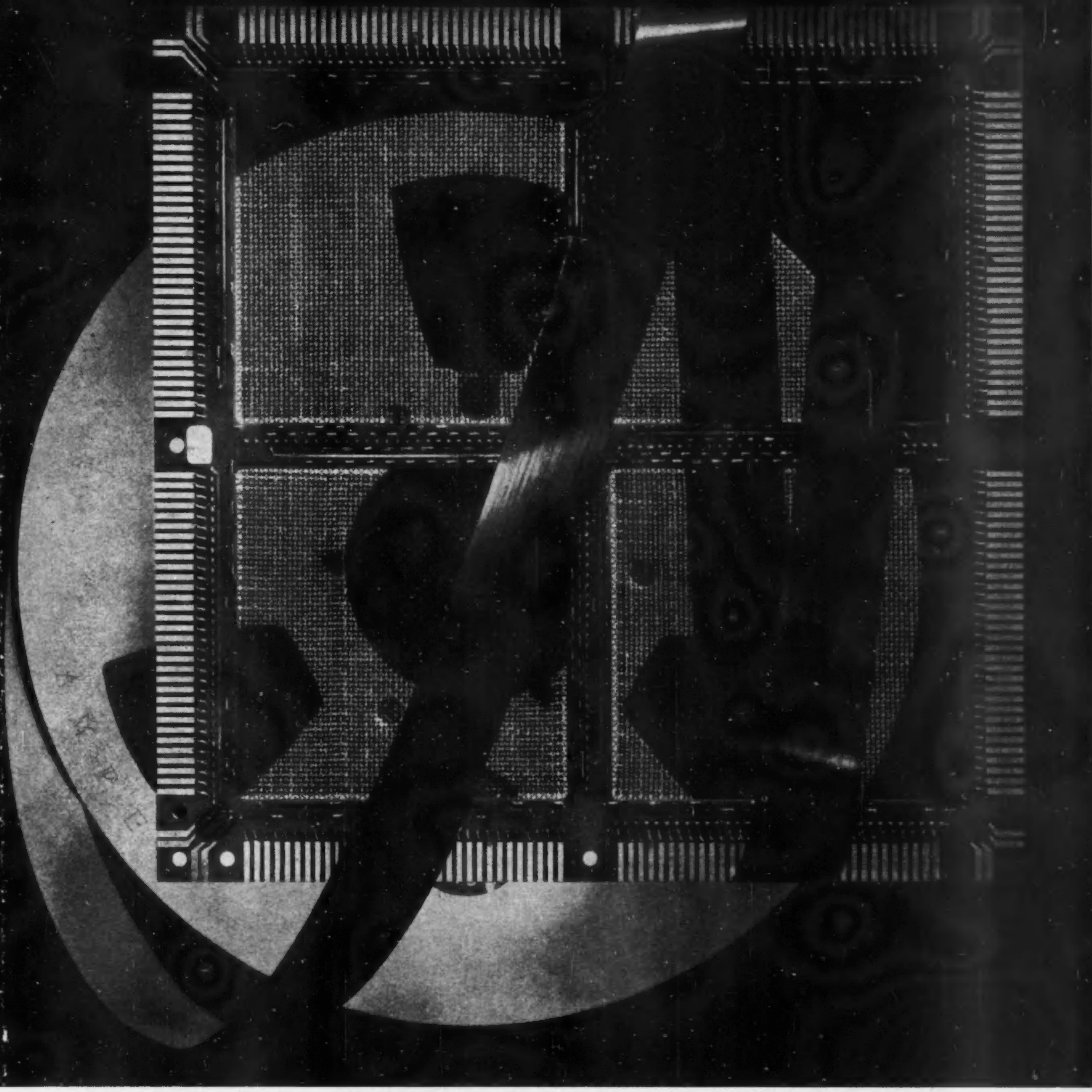
V_m = downstream volume of the mixture, cu ft
V_{L2} = downstream volume of the liquid, cu ft
V_{G2} = downstream volume of the vapor, cu ft
f = fraction of liquid vaporized
W = weight of saturated liquid upstream, lb mass
v_{L2} = specific volume of liquid downstream, cu ft/lb
v_{G2} = specific volume of vapor downstream, cu ft/lb
G = specific gravity of the vapor liquid mixture
G_L = specific gravity of the saturated liquid upstream

a) $V_m = V_{L2} + V_{G2}$ d) $f = (h_{L1} - h_{L2})/h_{LG}$
b) $V_{L2} = (1-f)Wv_{L2}$ e) $G = W/62.4V_m$
c) $V_{G2} = fWv_{G2}$

f) $$G = \frac{W}{62.4} \times \frac{1}{Wv_{L2}[1 - (h_{L1} - h_{L2})/h_{LG}] + Wv_{G2}(h_{L1} - h_{L2})/h_{LG}}$$

Now if $G_L = W/62.4$ and for most cases $V_{L2} \approx 1$, then

g) $$G = \frac{G_L}{1 + 62.4G_Lv_{G2}(h_{L1} - h_{L2})/h_{LG}}$$



Two vs Three-Gyro Guidance Platforms—I:

HOW THEY COMPARE

THE GIST: There are two types of inertial guidance platforms in general use today. Each uses a different kind of gyro. An examination of how these platforms respond to various accelerations and mass shifts reveals that neither type is inherently superior to the other and that the performance of either one depends on its application and the precision with which it is built.

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The gyro platform, the "inner ear" of today's inertial guidance systems, uses gyros, accelerometers, and integrators to establish and maintain a reference coordinate system with respect to the Earth. Two major types of such stable platforms are in general use today—namely, two and three-gyro platforms. Each of these platform types uses a different kind of gyro. One of these is the "single degree of freedom" gyro, which is a rate-integrating device. The other is the "two degree of freedom" gyro having an output of two attitude angles. Both types are floated to keep their gimbal bearings unloaded.

Three gyros of the single degree of freedom type are needed to constitute a complete platform that will serve as a reference base for three orthogonal coordinates. Each of the three gyros stabilizes a single axis. This is the three-gyro platform.

On the other hand, two gyros of the two degree of freedom type can also establish the coordinate system. Each of the gyros provides two attitude angles, and since the reference system needs only three of these angles, one output is redundant. This is the two-gyro platform.

The following comparison of platform types stays within the present state of the art; drastically new developments now under way are not discussed.

To limit discussion to the areas in which the two systems differ from each other, areas common to both types of systems, such as the gyromotor, the outer-roll gimbal loop, etc., are not treated.

HOW THE PLATFORMS DIFFER

The main purpose of a stable platform is to establish an accurate reference base for accelerometers, which in turn measure the instantaneous accelerations in three orthogonal directions. Accuracy of this measurement is a major factor in the determination of position error.

In the three-gyro platform, Figure 1A, the reference plate is the azimuth frame, supported by a gimbal system and carrying three single degree of freedom gyros. The plate is stablized around the three axes. A pickoff on the precession axis of each gyro generates an error signal when disturbing forces tend to tilt the reference plate. This signal passes through the stabilization amplifier into the torque motor mounted on the gimbal. The motor develops a torque equal and opposite to the disturbing torque. In this system each gyro plays an active part in keeping the reference plate level. The accelerometers are mounted directly on this plate.

In the two-gyro platform, Figure 1B, the two degree of freedom gyros are isolated by their gimbals from the reference plate (azimuth frame). As in the three-gyro platform, this frame carries the accelerometers and is in turn supported by a gimbal system. Each gimbal axis carries a torque motor and each gyro contains two position pickoffs that produce error signals when the frame deviates from the gyro position. The torque motor outputs restore the frame to the gyro position. This system is characterized by the fact that the gyros take no active part in providing the restoring torque; they merely indicate deviation of the frame and produce error signals. This then is a pure followup system.

The difference between the two systems can be demonstrated simply by cutting the servoloops. The two-gyro platform will turn away under the slightest disturbance, whereas in the three-gyro platform the gyros will start to precess and tend to maintain a level platform. Thus the gyros in the two-gyro platform are indicators; those in the three-gyro platform have indicating and stabilizing capabilities.

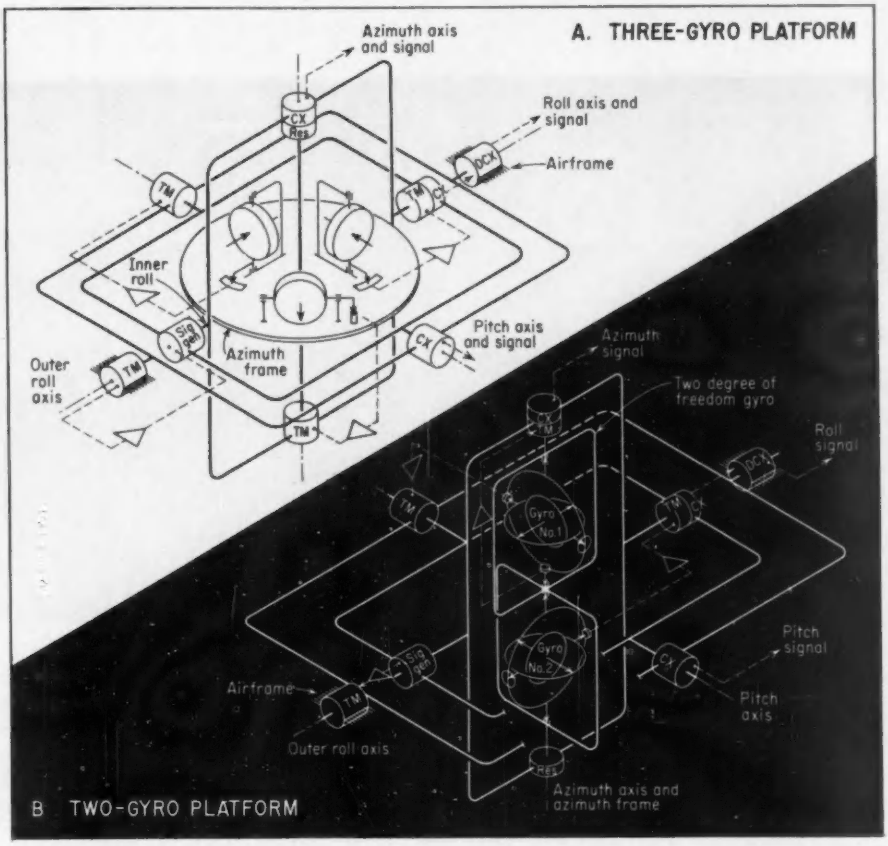


FIG. 1.
Three-gyro and two-gyro platform configurations. In both types, three accelerometers (not shown) are mounted on the azimuth frame, and control signals for pitch and inner roll pass through the azimuth resolver before entering the torque motors.

MAJOR ERROR SOURCES

In general there are two kinds of errors: those inherent in the system as a result of design and designated as systematical errors and those arising from faulty production. Only the systematical errors will be considered here. These are:

1) errors resulting from mass shift within the gyro itself (mass shift is an internal gyro error and does not stem from imperfections in the plate to which the gyro is attached)

2) gyro drift caused by oscillations of the stabilized plate (this drift is considered an external gyro error because it depends on circumstances outside of the gyro—on the motions of the plate).

Design of a good gyro depends mainly on the skill and experience of the designer and his ability to control mechanical and thermal stresses and thereby to minimize mass shift. He must also control the isoelasticity of his design to prevent drift resulting from vibrations. The following assumes that the gyros of both systems are equally isoelastic, but may have small mass shifts along their orthogonal axes.

In two degree of freedom gyros

The sketch at the top of Figure 2 shows the gimbal configuration of a two degree of freedom gyro. The letters x, y, and z describe a coordinate system attached to the gimbal axes, where x lies along the spin axis, y along the inner precession axis, and z along the outer precession axis. To introduce accelerations a second coordinate system, *A-B-C*, is needed. The first system is parallel to this. The following assumes that accelerations take place sequentially along the *A*, *B*, and *C* axes, and that during each acceleration, mass shifts occur sequentially in the x, y, and z directions. In other words there are six variables: three accelerations and three mass shifts. The object of this investigation will be to see what happens when one variable is changed while the other five are held constant. A mass shift along the spin axis (x) will be considered a major mass shift (double circle around the axis designation) while a mass shift along the y or z axis will be considered a minor mass shift (single circle around the axis designation). This is simply because a gyro cannot be made as stable along its spin axis as along its other axes.

Suppose an acceleration takes place along *A* and a mass shift along x. This mass shift produces no torque (see chart accompanying Figure 2A). However, a mass shift along y generates a torque around z, and a mass shift along z develops a torque around y. The torque z forces the gyro to precess around y, and the torque y forces the gyro to precess around

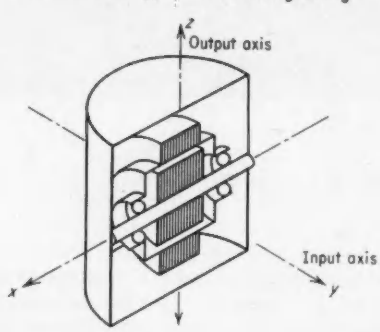
A. TWO DEGREE OF FREEDOM GYRO

Direction of acceleration along	Mass shift along	Torque produced around	Drift around
A axis	x y z	— z y	— y z
B axis	x y z	z — x	y — —
C axis (gravity)	x y z	y x —	z — —

This gyro has to be balanced around all three axes

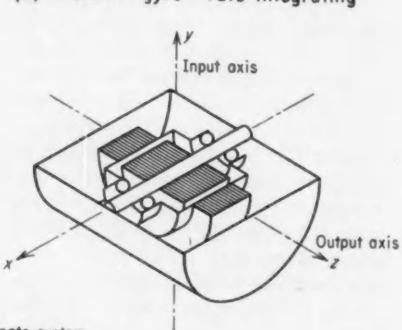
B. SINGLE DEGREE OF FREEDOM GYRO

(1) Vertical gyro – rate integrating



Direction of acceleration along	Mass shift along	Torque produced around	Drift around
A axis	x y z	— z y	— y —
B axis	x y z	z — x	y — —
C axis (gravity)	x y z	y x —	— — —

(2) Azimuth gyro – rate integrating



The coordinate system was turned with the gyro to the new position

Direction of acceleration along	Mass shift along	Torque produced around	Drift around
A axis	x y z	— z y	— y —
B axis	x y z	y x —	— — —
C axis (gravity)	x y z	z — x	y — —

Legend: ○ denotes minor shift or drift
◎ denotes major shift or drift

FIG. 2. Acceleration and mass shift effects on a two degree of freedom gyro, A, and a single degree of freedom gyro, B.

z. Since the y and z-axis mass shifts are of a minor nature, they produce minor drifts.

If the acceleration occurs along *B* and the mass shift takes place along x, a torque develops around z and a major drift around y. If the mass shift is along y, nothing happens. A mass shift along z produces a torque around x, but this cannot cause the gyro to precess.

Acceleration along *C* and mass shift along x produce torque around y and major drift around z. If the mass shifts along y, a torque occurs around x, but no drift takes place. Mass shift along z has no effect.

In single degree of freedom gyros

The sketches, Figure 2B, show the gimbal configuration of two functions of the single degree of freedom gyro. In one case (1) the gyro is used as a vertical gyro for stabilizing a horizontal axis; in the other case (2) the gyro provides azimuth stabilization. Regardless of the application, the coordinate system remains fixed to the gyro with x along the spin axis, y along the input axis, and z along the output axis. For the vertical gyro (1) the coordinate system is parallel to the reference system A-B-C along which accelerations are applied. However for the azimuth gyro (2) the coordinates y and z are interchanged; y is now along C and z is along B.

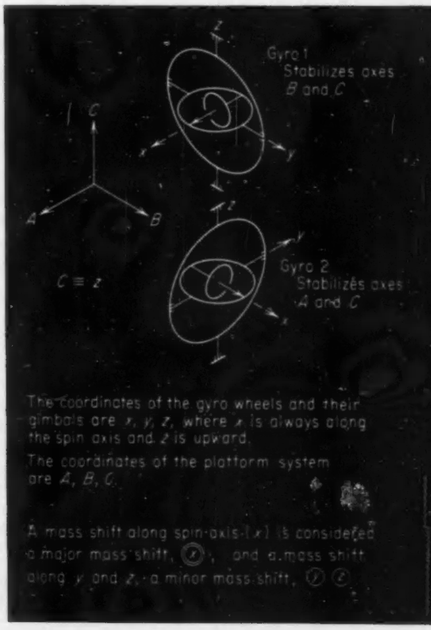
Under the same assumptions of mass shift and acceleration as before, drifts will occur as tabulated in the last two charts of Figure 2. When an acceleration occurs along A and mass shifts along x, y, and z, torques are produced around z and y, but only the torque around z can cause a gyro drift. The torque around y acts against the precession bearings. An acceleration along *B* in the case of the vertical gyro or C in the case of the azimuth gyro and corresponding mass shifts along x, y, and z generate only one major drift rate—around y. Accelerations along the one remaining axis cause no drift at all.

On the basis of the results given in these last two charts it may be said that under conditions of an arbitrary acceleration and an arbitrary mass shift, the single degree of freedom gyro drifts only when a torque is developed around the output axis. The drift therefore occurs around its input axis. A mass shift along the z axis has no effect and therefore it may be concluded that the single degree of freedom gyro does not require balancing around the x axis other than that required to minimize vibration.

On complete platforms

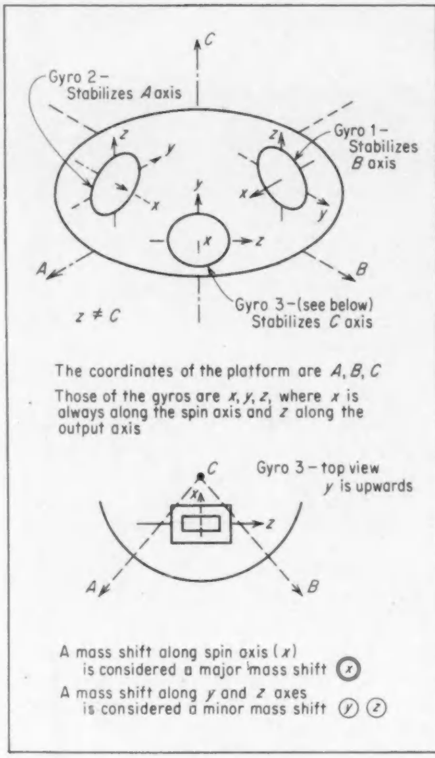
Consider now the effects of mass shift on complete stable platforms. The drawing in Figure 3 shows the gyro arrangement on a two-gyro platform. Gyros 1 and 2 are identical but gyro 2 has been turned 90 deg around the z axis with respect to gyro 1. This means that the x and y coordinates of gyro 2 have been interchanged with those of gyro 1.

In performing their stabilization role, the gyros transmit their drift rates to the platform, thus causing the platform to drift with them. An investigation similar to that used for the gyros alone produces the effects listed in the chart of Figure 3. In general, under the effect of a horizontal acceleration,



Acceleration in direction of	Mass shift along	Torque produced around	Drift around
	Gyro 1		
A	x	—	
	y	z	(y) B
	z	y	C
B	x	z	(y) B
	y	—	—
	z	x	—
C (gravity)	x	y	C
	y	x	
	z	—	
	Gyro 2		
A	x	z	(y) A
	y	—	—
	z	x	—
B	x	—	—
	y	z	(y) A
	z	y	C
C	x	y	C
	y	x	—
	z	—	—

FIG. 3.
Gyro behavior on a two-gyro platform.



Acceleration in direction of	Mass shift along	Torque produced around	Drift around
Gyro 1 (B axis)			
A	x y z	— z y	— (y)B —
B	x y z	z — x	(y)B — —
C	x y z	y x —	— — —
Gyro 2 (A axis)			
A	x y z	z — x	(y)A — —
B	x y z	— z y	— (y)A —
C	x y z	y x —	— — —
Gyro 3 (azimuth)			
A	x y z	0.7y 0.7z 0.7y	— (y)0.7C —
B	x y z	0.7y 0.7z 0.7y	— (y)0.7C —
C	x y z	z — x	(y)C — —

FIG. 4.
Gyro behavior on a three-gyro platform.

one of the gyros has a major drift around one horizontal axis; the other gyro has a minor drift around the second horizontal axis, plus a minor drift around the vertical axis. If the acceleration is along the axis C, the two gyros drift around the axis z.

The configuration of the three-gyro platform is shown in Figure 4. Gyro 1 stabilizes the *B* axis, gyro 2 the A axis, and gyro 3 the C axis (azimuth). Because the spin axis of gyro 3 intersects the right angle between A and *B*, this gyro behaves differently under accelerations. For example an acceleration along A is sensed as 70 percent along the x axis and 70 percent along the z axis. An acceleration along *B* has a similar effect. Results of these and other accelerations are shown in the chart. Note that the azimuth gyro has a drift of 70 percent of a given minor drift for either horizontal acceleration.

The results listed in the chart lead to some interesting conclusions. Under the effect of a horizontal acceleration all the gyros drift. One vertical gyro has a minor drift around one horizontal axis while the other vertical gyro has a major drift around the other horizontal axis. As noted above, the azimuth gyro drifts 70 percent of the minor drift. An acceleration along the vertical axis C has no effect on either vertical gyro. However its effect on the azimuth gyro is a major drift around C.

It may in general be said that both platform types behave the same under the effect of an acceleration with components along A, B, and C and gyro mass shifts along x, y, and z. They drift around one horizontal axis at a major rate and around the second horizontal axis at a minor rate. The drift rate in azimuth is only 70 percent for the three-gyro platform. Each azimuth gyro of the two-gyro platform has a 100-percent drift rate, but this can be reduced to 70 percent by an averaging circuit.

Under the effect of vertical accelerations (including gravity) the two-gyro platform has the smaller azimuth drift rate, whereas under the effect of horizontal accelerations, the three-gyro platform has the smaller drifts. Therefore, the performance of either platform depends on the application. In the case of a smooth-flying aircraft, the two-gyro platform might have an advantage. For fighter aircraft and rockets, the three-gyro configuration is preferred.

POINTS TO REMEMBER

1) Bearing play along the precession axis of the single degree of freedom gyro does not produce a disturbing torque, but similar play along the inner precession axis of a two degree of freedom gyro makes it sensitive to accelerations along the spin axis, and it will drift. A bearing with extremely small play and friction attached to a small, lightweight gimbal is no mean production feat.

2) Gyro gimbal deformation is the same as bearing play. A single degree of freedom gyro does not have this critical gimbal.

3) A single degree of freedom gyro requires precise balancing only around its output axis, whereas a two degree of freedom gyro requires balancing of itself and its gimbal around its two output axes.

Terminology for Functional Characteristics of Analog-to-Digital Converters

Expanding utilization of digital computers, digital display devices, and digital decision elements in conjunction with analog measurements has fostered active use of analog-to-digital converters. To apply the converters an engineer needs uniform data on their characteristics. He is confronted, however, with nonuniform means of specifying the characteristics. To develop uniformity, the authors, as members of the Component Specifications Subcommittee of the AIEE Feedback Control Systems Committee, have prepared tentative recommendations (AIEE paper number 61-15, to be presented this month at the AIEE Winter General Meeting) for describing and testing the major characteristics of Voltage-to-Digital (VDC) and Shaft Position-to-Digital (SDC) Converters. This data file covers their recommended terminology for *functional* characteristics.

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Quantity Factors

CODE (SDC and VDC) is the relationship between a set of quantized outputs and the values of points of the continuous input they represent. Examples: binary, modified binary (cyclic, gray), coded wave shapes (pulse width), octal, binary coded decimal.

TOTAL COUNT (SDC and VDC), the full scale reading of the converter, equals the maximum number of discrete quantization increments available from the converter. For a binary coded converter of n bits, the total count is 2^n.

COUNT PER TURN (SDC) is the total number of discrete quantization increments produced by one revolution of the input shaft.

POSITIVE INPUT DIRECTION (SDC) is the direction of input motion that produces an increasing output count.

ZERO CROSS-OVER ANGLE (SDC) is the position of the input (for positive input direction) at which the output count changes to zero. In a binary coded SDC it is the position at which the count changes from all "ones" to all "zeroes".

CROSS-OVER ANGLE (SDC) is the angular position (measured in a positive direction from the zero cross-over angle) at which a change in count should occur. Each quantization increment is associated with a nominal cross-over angle.

VALUE OF COUNT (SDC and VDC), the nominal input value (either voltage or angle) that corresponds to a particular count, is defined as the arithmetic mean of the theoretical input region (cross-over angles for an SDC and input voltages for a VDC) over which the output could occur.

Quality Factors

RESOLUTION (SDC and VDC) is a measure of the smallest input change detectable at the output of the converter. See Figure 1. For a VDC it is expressed in input voltage and is a function of the signal-to-noise ratio, the gain, and the size of the least significant bit. For an SDC it is expressed as the reciprocal of the total count or its angular equivalent and it is a function of the size of the least significant bit.

REPEATABILITY or **PRECISION** (VDC) is a measure of the reproducibility of several independent quantizations (counts) of a fixed input under fixed environmental and operating conditions. See Figure 1. It is affected by friction, hysteresis, and nonrepetitive noise effects, as well as by the digital

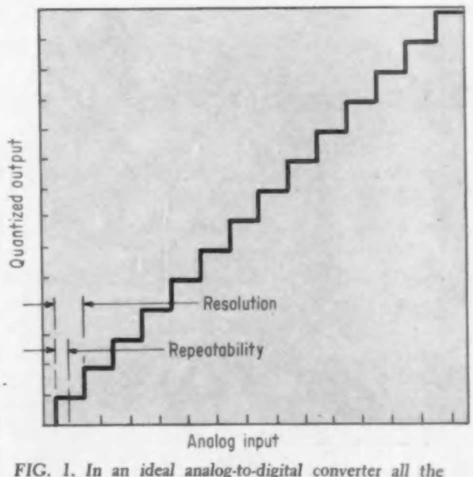

FIG. 1. In an ideal analog-to-digital converter all the steps have the same height and the same width; a unique digital value corresponds to any value of the analog input.

resolution of the output. Time duration and all conditions must be stated. High repeatability does not necessarily imply accuracy; an erroneous quantization could be highly repeatable.

ZERO OFFSET (VDC) is the magnitude of the output reading, referred to the input, when the input is zero. It is normally given in absolute input units to make it equivalent to an input error signal.

DRIFT (VDC) is a measure, in absolute units, of the change in zero offset as a function of time.

TOLERANCE (SDC and VDC) is the fraction of the total count by which a quantization differs from the true quantized value of the input signal after correction for zero offset. See Figure 2.

DEVIATION (SDC and VDC) is the fraction of the true quantized value by which the measured quantized signal varies from the true value after correction for zero offset. See Figure 2.

LINEARITY (VDC), a measure of the constancy of the ratio between output reading and input value, is based upon the deviation from a straight line drawn between the zero and total count (i.e., after correcting for zero offset and gain errors). Deviation is expressed as a percentage of total count.

MONOTONICITY (SDC and VDC) is an incremental linearity and is defined as the variation in the ratio between the incremental change in output and the input change necessary to produce the incremental change in output.

QUANTIZATION UNCERTAINTY (SDC and VDC) is the fraction of the quantum or its equivalent input signal by which discrete output levels are separated by regions of uncertainty of the input quantity. An ideal analog-to-digital converter would have the characteristic shown in Figure 1. If all the steps were present and had the same height and the same width, the converter would be linear and monotonic. If the separation between successive steps had zero width, a unique digital value would correspond to any value of the analog input. In practice this is impossible; see Figure 3.

TOTAL CONVERTER ERROR (SDC and VDC) is the maximum difference between the true input value for a given output count and the actual maximum or minimum input value that produces the same output count. It may be expressed in input units or as a percentage of full-scale input.

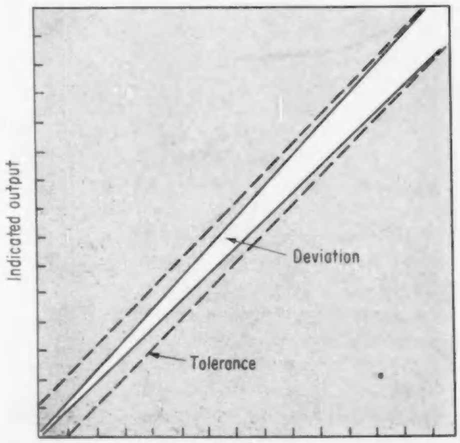

FIG. 2. Specifying deviation, rather than tolerance, demands more of the converter because maximum error must decrease as the signal amplitude decreases.

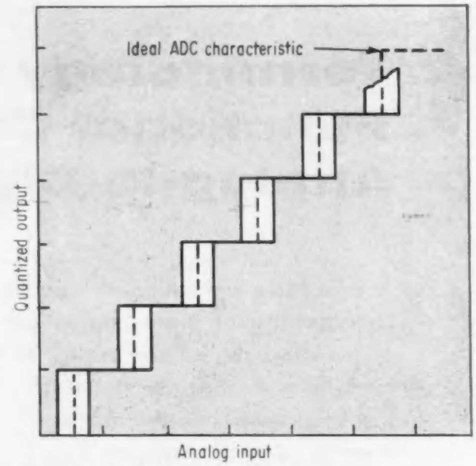

FIG. 3. Shaded area demonstrates the zone of quantization uncertainty which occurs in practice.

ABSOLUTE ERROR (SDC and VDC) is the absolute value of the total converter error, expressed in the units of the full-scale input. A combination of all the contributing sources of inaccuracy, it is normally not a simple algebraic summation of the individual factors. If its nature is statistical, confidence intervals, as well as the mean, must be defined.

Dynamic Factors

MAXIMUM ALLOWABLE INPUT RATE (SDC and VDC) is the maximum change in input quantity in a unit of time. For an SDC its units are RPM and it depends upon the dynamic response of the readout means used (bounce and natural frequency for brush-type readout; response time for photocell readout; circuit sensitivity for other types of readout). For a VDC its units are volts per unit of time and it depends on the response of the conversion circuitry.

CONVERSION TIME (VDC) is the time required to convert an analog signal to a digital code. Specification in both unit time per bit and unit time per conversion are significant because some converters use a varied rate to allow longer settling times for the more significant bits.

CONVERSION RATE or **READOUT RATE** (SDC and VDC) is expressed in terms of the number of discrete outputs (corresponding to discrete inputs) that may be obtained in a unit of time. For a VDC the unit of time is the sum of the settling time and the total conversion time. In specifying conversion rate, the control system designer must establish whether the converter has special logic functions such as automatic range selection and polarity selection.

REFERENCES

1. *NOTES ON ANALOG-TO-DIGITAL CONVERSION TECHNIQUES*, Alfred K. Susskind, Technology Press, MIT.
2. *HANDBOOK OF AUTOMATION, COMPUTATION, AND CONTROL*, edited by E. M. Grabbe, S. Ramo, and D. E. Wooldridge, Vol. 2, Chapter 20, John Wiley and Sons, N. Y.
3. *DIGITAL CONVERTER ACCURACY: TERMS AND DEFINITIONS*, S. L. Plahaty, Norden Laboratories.

Transistorized Circuitry for Road Machinery Control

THE GIST: Applying automatic electronic control to a piece of basic machinery like a road grader raises a difficult problem: how to compensate for time delays introduced by such mechanical characteristics as backlash, friction, and elastic deflection of linkages. The authors describe an all transistor control that solves this problem with a simple but clever computing circuit so that no alterations are required to the basic machine. In fact, the automatic control cabinet sits next to the manual control lever and actuates the same mechanical linkages. The control applied to the blade of the road grader reduces the tedious part of an operator's job.

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Common obstacles to the application of automatic feedback control equipment to existing basic machines are the time lag and positioning uncertainty introduced into drive trains by such mechanical deficiencies as backlash, elastic windup, and friction. Replacing or upgrading the drive train, particularly if large amounts of power have to be transmitted, may not be feasible because of the expense. Often it is also necessary to retain conventional manual controls for special situations. Both of these requirements influence the design of controls for construction machinery.

Despite these restrictions, however, construction machinery is a good potential application for automatic control. The first construction machine electronic control system, developed to automatically regulate the slope of the leveling blade on a motor grader, illustrates how these restrictions can be satisfied with a relatively inexpensive, reliable design.

The motor grader is the most versatile, yet the most precise of modern heavy construction machines. Its unique function in roadbuilding and airport construction is to shape the earth to a prescribed cross section. In a modern highway, for example, cross sections are the same for thousands of feet in the direction of travel, and good riding quality at high speeds requires that tolerance on cross slope be held to a fraction of an inch in the width of a lane.

To achieve such tolerances with purely manual control, an operator with a "good eye" must closely follow an elaborate network of carefully surveyed reference stakes. This monotonous, but precise, slope control task is well suited to automatic control.

Control requirements

Because of the tight tolerance on the graded surface, the static repeat accuracy of the control has to be ⅛ in. in 10 ft of surface width. This is an angular tolerance of 3 min of arc, or 0.06 percent of the total control range, which was chosen to be 90 deg, 45 deg above and below the horizontal.

The position of the blade relative to the frame is adjusted by means of four independent linkages (Figure 1): right lift, left lift, side shift, and blade rotation. Minor changes in the transverse slope of the surface being cut are made by adjusting one of the two lift linkages.

Under manual control the operator moves these linkages by manipulating either of two control levers which position dog clutches or hydraulic spool valves (depending on the particular grader design). In either case the control element is an on-off device. Rate of correction is proportional to engine speed; thus the amount of correction must be controlled by the duration of engagement. The operator estimates the correction required and attempts to achieve it by moving the lever one or more times.

Because of the mass of the blade structure and the large external forces applied to it, each lift drive must deliver about 3 hp to the linkage at maximum lift speed (about 0.30 ft per sec). To simplify installation, existing clutches and drive train are used for automatic as well as manual control.

Since the operator regulates the elevation of the blade structure manually, following a reference line on one side of the grader, that end of the blade has been left under conventional manual control. The other end is controlled automatically to maintain the desired transverse slope on the graded surface. The actuator for automatic control is external to the existing drive train and coupled to it via the

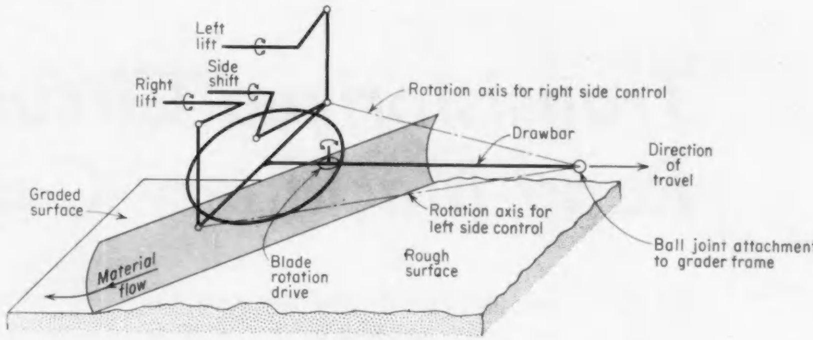

FIG. 1.
Geometry of the grader blade. The blade is adjusted by four independent linkages (heavy lines).

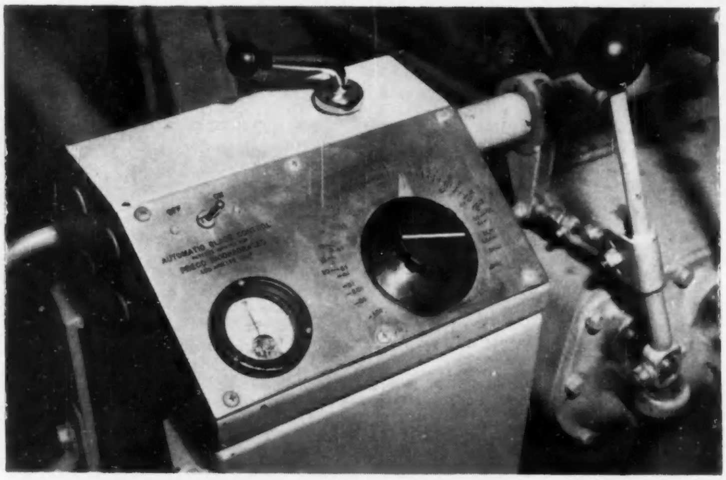

FIG. 2.
Automatic control installed beside the manual control.

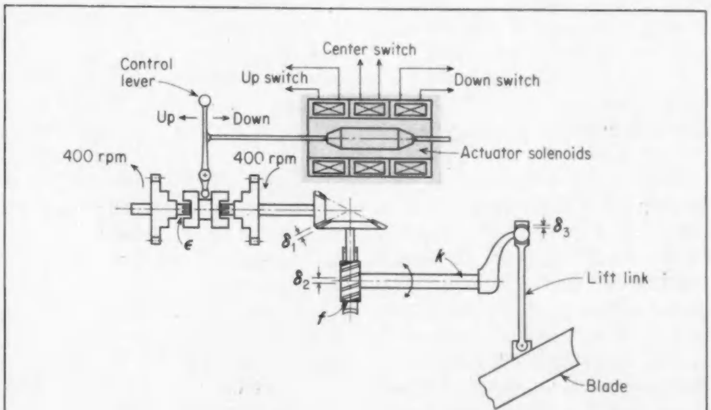

FIG. 3.
Blade lift gear train showing where mechanical deficiencies are introduced: ϵ is position uncertainty; δ_1, δ_2 and δ_3, backlash; f, dry friction; and k, elastic deflection. Automatic control (shaded) is applied to same linkage as manual control.

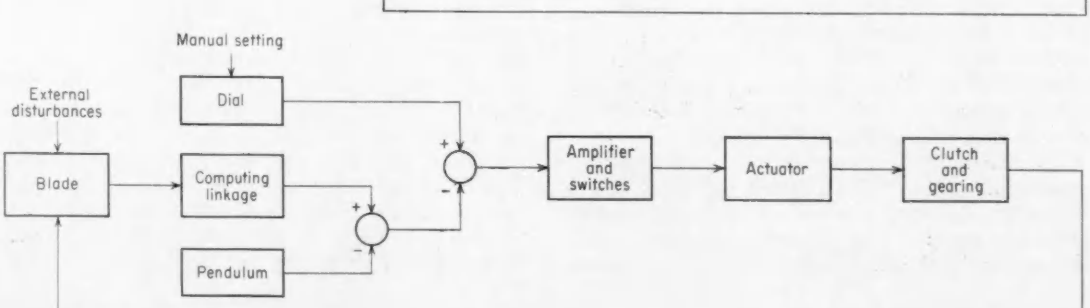

FIG. 4. Automatic control system.

manual control lever (Figure 2). Only the linkage attached to the left side control lever is shown. In the photo the selector on top of the actuator enclosure is shifted to provide automatic control on the left end of the grader blade.

A blade lift clutch and reduction gear train is shown in Figure 3. The clutch spool has two or three dogs which engage corresponding counter-rotating members to raise or lower the blade. Several stages of gear reduction and a final drive shaft produce crank rotation, hence blade motion. Although this mechanical system is rugged and quite adequate for manual operation, position uncertainty ϵ; backlash δ_1, δ_2, δ_3; dry friction f; and elastic deflection k result in effective time lags which might seriously limit automatic performance.

Under typical operating conditions a delay of about 50 millisec occurs from the start of clutch engagement to the start of blade movement. This delay may be longer than the time required to produce a minimum increment of blade movement so the control system must introduce a pulse of motion which is quenched before the load moves.

The amount of transverse slope correction which takes place for a given time of clutch engagement depends on engine speed, drive train slack, friction, lift crank position, and blade attitude. Engine speed can vary over a 3 to 1 range. Because vehicle speed usually has the same dependence, slope change per foot of forward travel remains relatively constant. If the crank is parallel to the lift link, the rate of slope change will be zero. An experienced operator will work with crank and link nearly perpendicular.

The effective drive gear reduction is influenced by blade position in a more subtle way. A motor grader is almost never operated with the blade transverse to the direction of travel. Normal orientation for flat grading is shown in Figure 1, almost 45 deg with the direction of travel: cut material would be cast laterally to the right of the grader. In this position the transverse slope changes rapidly with right side control since the cutting edge is nearly perpendicular (in plan view) to the axis about which the blade system rotates. Conversely the transverse slope changes slowly with left side control since the cutting edge is nearly parallel to the rotation axis. The ratio between the two rates of slope change is about 3 to 1. In more extreme blade positions (used for sloping banks) even greater changes in drive ratio occur.

One way to handle these variations in speed and drive ratio would be to measure the correction rate directly and use the resulting signal to vary engagement time. This approach is frustrated by the difficulty of measuring angular correction rates as low as 0.01 radian per sec and by the time delay in the drive train, so that the clutch must sometimes be disengaged before the blade has moved. The rate signal would thus be obtained too late to be useful. A second approach, which has been successful experimentally, is to measure electrically the principal angles which determine blade orientation and use this data to vary the engagement time.

A simpler way is the timing system shown in Figure 4. In combination with the grader control characteristics, it proved relatively tolerant of the wide range of correction rates.

System design

The operator sets the slope dial to cut the required transverse slope and selects the end of the blade which is to be under automatic control. The actual blade slope is measured and compared with the vertical reference, a heavily damped pendulum suspended about a horizontal axis approximately parallel to the direction of travel. The actual and required slopes are compared in a bridge circuit, using precision potentiometers as angle transducers. Any discrepancy is amplified and used to actuate the grader clutch and gear train. Thus the blade slope is restored to the required value. Disturbances of the blade slope arise from two sources—roll of the grader frame due to blade loads or surface irregularities, and elevation changes of the manually controlled end of the blade imposed by the operator.

The position sensing bridge circuit and electronic system operate from a nominal 6-vdc electrical supply. Because of the low bridge supply voltage and high ratio of operating range to threshold error, considerable error signal amplification is required. Circuitry based on the use of germanium transistors as active elements was chosen to provide a good balance of the following requirements:

1. *high reliability*
2. *long service life*
3. *moderate cost*
4. *minimum null drift*
5. *acceptable performance in the ambient temperature range 0 to plus 130 deg F*
6. *low supply voltage.*

The dc error signal from the bridge circuit is converted to a 20-kcps voltage by a transistor modulator (Figure 5). With three stages of ac amplification, the signal undergoes 70-db of gain before a synchronous demodulator. A zero-center meter connected across the demodulator output allows accurate zeroing of the system to compensate for cutting edge wear. Because the meter is a reliable indicator of departure from required slope, it can be used as a guide for manual control of the blade.

The demodulator output is routed to the up and down switching circuits through a reversing switch to preserve the proper sense of blade motion as automatic control is transferred to right or left side gear trains. This switch is operated by the selector which mechanically couples the solenoid actuator to either of the blade control levers on the grader. In turn, the switching circuits control contactors which operate the actuator solenoids. These circuits are

completely transistorized, employing a Schmitt trigger, such as shown in Figure 6, to drive a power transistor controlling current to the contactor coil.

The actuator armature is magnetically pulled up or down depending on which switching system is conducting. The dog clutch is engaged to produce blade rotation in the proper direction. When the solenoid is deenergized, the teeth disengage and the clutch moves toward its central neutral position. However, because of inertia, the clutch tends to overshoot and can then oscillate for some time between up and down engagements. To prevent oscillation and reduce disengagement time, a centering solenoid is switched on immediately after either the *up* or *down* solenoid is switched off, through a circuit that receives its input from the outputs of the up and

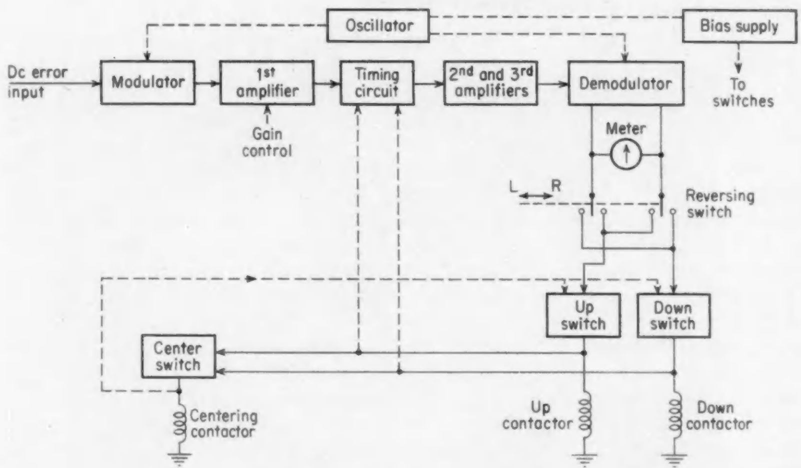

FIG. 5.
Amplifier and switches. After amplification, demodulation output is routed to proper circuit by a reversing switch.

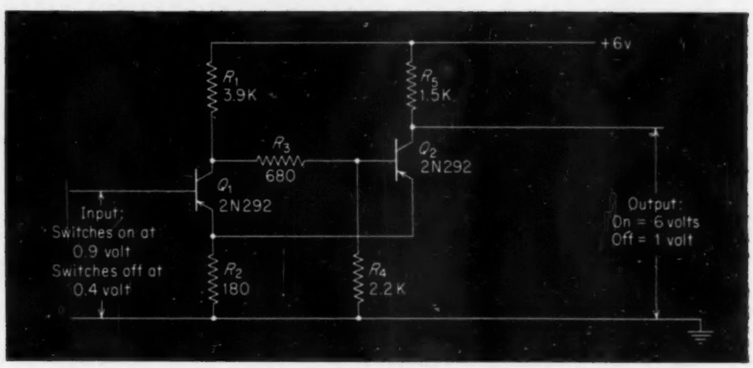

FIG. 6.
Triggering circuit controls contactor which operates actuators.

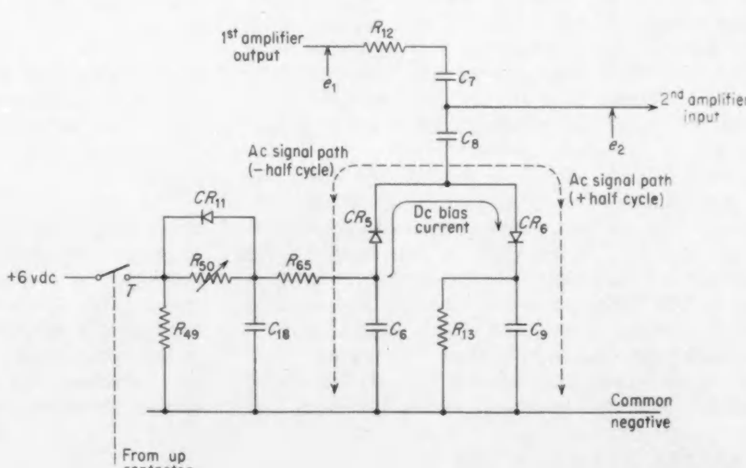

FIG. 7.
Timing circuit. Resistor R_{12} and diode pair CR_5 and CR_6 make up a variolosser network. When dc bias current is zero, the network causes little attenuation of first amplifier output. When the up contactor is energized, point T is raised from common negative to plus six vdc. This charges capacitor C_{18} through resistor R_{50}. As the voltage across C_{18} increases, the bias current increases—decreasing the resistance of the diode pair. Thus the signal from the first amplifier is decreased. Diode CR_{11} discharges C_{18} when the up contactor opens.

down switches. A sterilizing circuit insures that neither the up nor down switch can conduct while the center contactor is energized. The circuit (Figure 7) which controls clutch engagement time is interposed between the first and second amplifier stages. It acts to reduce system gain with time from the instant either the up or down contactor is energized.

The performance of the timing circuit is shown in Figure 8A. Any characteristic curve between (1) and (3) may be obtained by an adjustment of R_{50}. This adjustment plus one for down operation and an over-all gain adjustment are all that are needed to match the control to a motor grader.

System operation

If an error in blade slope greater than the threshold value arises in the sense which requires operation of the up switch, the amplified and demodulated signal reaches the up trigger with very little time delay and the up contactor is energized shortly thereafter. The timing circuit begins to attenuate the error signal along, for example, curve 3, Figure 8A. After an initial delay the blade begins to move, and position error is corrected at a constant rate as shown in Figure 8B. Trigger input, being the product of error and attenuation, falls more rapidly to the cutoff level, Figure 8C. After the trigger turns off, the blade continues to move because of inertia and windup effects, perhaps overshooting the zero error position somewhat as shown. If the rate of position correction is slower, the trigger remains on for a longer time, thus tending to produce more nearly the same total correction.

The control behaves very much like a human operator. If the error is observed to be large, the control lever is engaged steadily until zero is approached, then disengaged and, after another observation, perhaps a small additional correction is made. Because of dry friction and clutch tooth orientation, the dynamic performance of the system is difficult to specify in a simple quantitative way. However, performance of the automatic control is fast and accurate enough to represent a substantial improvement over human capabilities.

Blade geometry

One unusual feature of the motor grader problem is the difficulty in measuring the variable to be controlled: the true transverse slope of the graded surface. Usually the motor grader travels along a course which is nearly at a right angle to the cross section in which slope is specified. Therefore the transverse slope of the surface being cut is the projection of the cutting edge into a plane normal to the direction of travel or approximately normal to the center line of the grader. Since the blade suspension allows arbitrary orientation of the cutting edge with respect to the grader frame, some means must be found to derive the required angle.

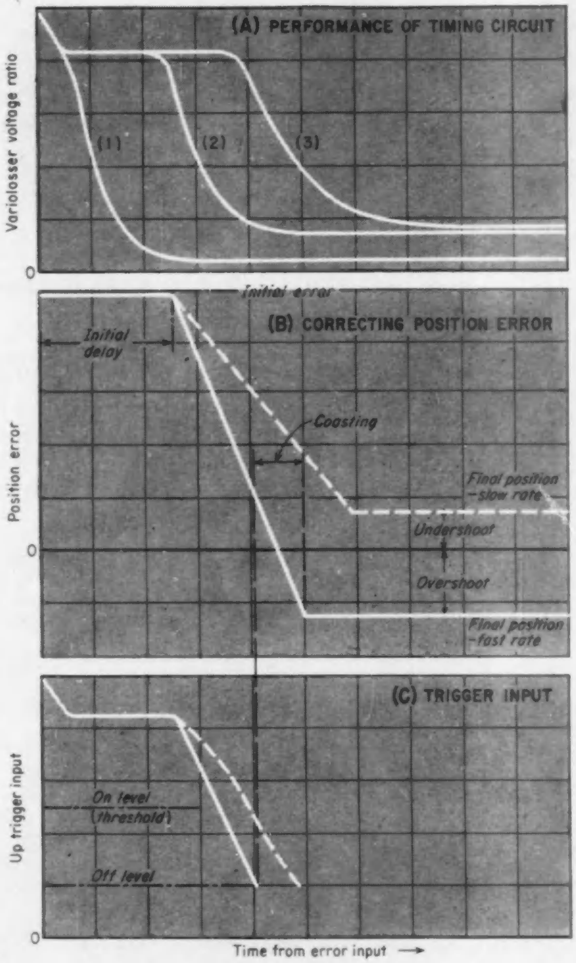

FIG. 8. HOW THE SYSTEM PERFORMS

Error in blade slope is amplified and demodulated, reaches the up trigger, and energizes up contactor. The timing circuit begins to attenuate along curve 3 in A, for example. After an initial delay the blade begins to move and position error is corrected at constant rate (B). Trigger input, the product of error and attenuation, falls more rapidly to the cutoff level in C.

With the blade transverse to the grader frame, the slope being cut is assumed to be zero. However when the blade is rotated 45 deg into a normal working position, the transverse slope becomes 3.5 percent or approximately 35 times the slope error tolerance for the system. This effect arises because the circle plane is not parallel to the grader wheel plane nor can it easily be made so in practice. An idea of the magnitude of error which arises if the blade geometry is ignored can be seen from Figure 9.

Theoretically the position of the cutting edge with respect to a coordinate system fixed on the grader frame can be defined by two angle measurements. Actually, three angles between the drawbar and frame would have to be measured as well as rotation of the circle with respect to the drawbar.

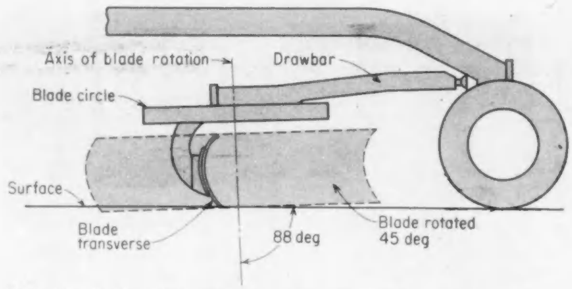

FIG. 9. Blade rotation increases magnitude of errors because circle plane is not parallel to the grader wheel plane.

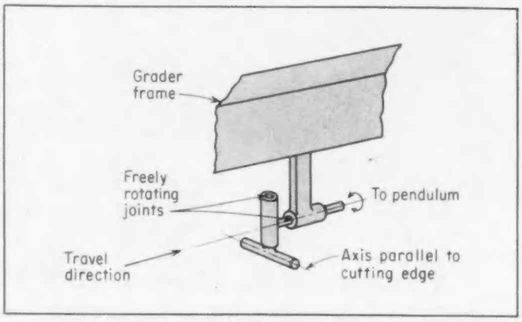

FIG. 10. Projecting mechanism.

Because of the required accuracy (better than 0.001 radian) and cost limitations, individual angle measurement and trigonometric combination seems unfeasible. Looseness between blade circle and drawbar and elastic deflection of the drawbar would introduce serious errors under some conditions.

Instead, a purely mechanical linkage was devised which transmits the cutting edge position into a structure fixed on the main frame and provides the projection into a transverse plane as a single shaft rotation. We need only compare this shaft angular position with the pendulum vertical reference to obtain the true transverse slope of the cutting edge.

On all motor graders the blade and circle structure can be raised and lowered and shifted laterally through distances of several feet. For stability the vertical reference is supported from the main frame. To prevent excessive telescoping of the mechanical linkage between blade structure and main frame, the vertical reference is anchored near the ball joint.

A hinge axis which is parallel to the cutting edge is supported from the blade structure. This axis is transmitted forward by a rigid framework containing discs at each end, the discs being caused to rotate together by a steel belt drive. Thus the lower axis in Figure 10 is constrained to be parallel with the cutting edge; in fact it becomes the cutting edge for control purposes. The two freely rotating "T" members perform the projecting function previously described, producing the desired angle component.

Although many of the components of the mechanical linkage have to be made with very high precision, they are still well within the scope of standard machining methods. Seven hinge joints are required: backlash is eliminated by preloading techniques. The vibration environment of the motor grader helps to reduce friction problems.

Reliability

The construction industry traditionally demands a high degree of reliability from the equipment it buys. Operating conditions are severe. Equipment is subject to rough handling: shock, vibration, dust, water, and temperature extremes equal or exceed those for which military ground support equipment must be designed. Maintenance and service are complicated by the fact that the equipment is frequently operated in remote areas where trained personnel and proper facilities are not at hand. As the first sophisticated control system in the construction industry, the automatic blade control suffered from the additional disadvantage of containing components unfamiliar to operators and servicemen.

Under these circumstances, it is not surprising that the original units required a considerable amount of attention to insure satisfactory operation. A major improvement in field reliability was achieved with the introduction of simple, centralized wiring and all-transistor circuitry to replace vacuum tubes and relays which were used in the first design. Exceptional reliability within a reasonable cost limit has been achieved by conservative design, careful debugging, the use of well-established components that are manufactured in large volume, and exhaustive production testing of each unit.

The pendulum potentiometer introduced a service problem at first. Torsional vibration, originating primarily in the grader engine, is transmitted into the pendulum potentiometer which measures blade position with respect to horizontal. Relative motion occurs between wiper and helical resistance winding consisting of a continuous dither at about 25 cps over one or two winding pitches superimposed on slow meandering—whenever the grader is in operation. If this motion is interpreted as an equivalent number of sweeps over the central position of the winding, the satisfactory service life of wiper and winding must exceed 10 million cycles.

The conventional wire-wound potentiometer design did not have such a life: wiper and winding wear and electrical noise soon developed in this service. On the other hand, the wire-wound potentiometer is by far the most economical angle transducer (in itself and considering related equipment) where high linearity is required. Multiple contact designs were developed, using precious metal windings which meet or exceed the life requirement. Continued sample life testing assures that the reliability level is maintained.

These and other lessons have been learned during some four years of field experience with the automatic blade control. The construction industry, properly conservative and skeptical at first, now accepts automatic control as another of its tools.

17 Ways to Measure Acceleration

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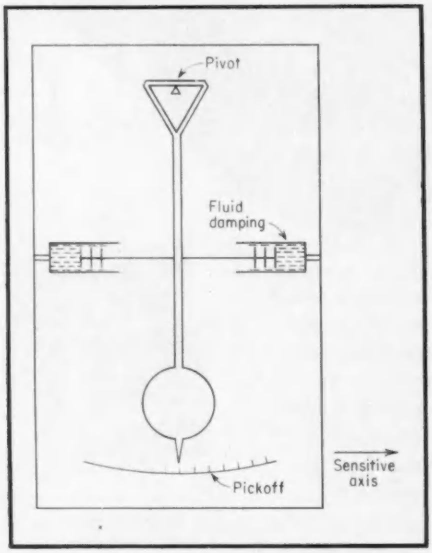
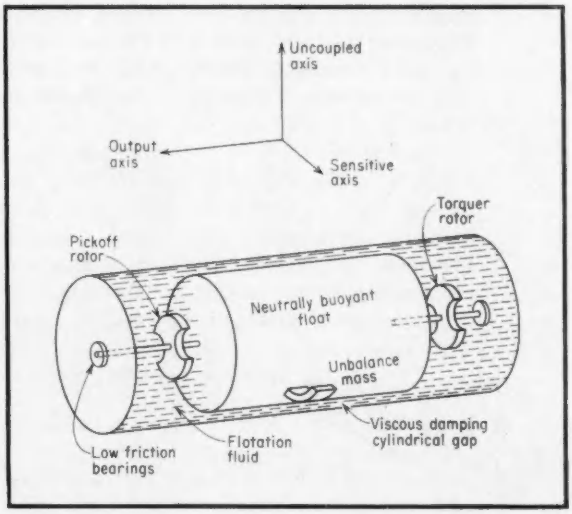
Accelerometers measure the force needed to prevent a so-called proof mass from being accelerated relative to the case within which it is mounted. Force and acceleration are proportional and of necessity in the same direction. The simplest instruments, in concept at least, involve restraint of linear motion of the proof mass. This restraint may be by spring extension, viscous shear, linear magnetic force motors, or some other such force inducer. A second class of accelerometers consists of pendulum-type devices in which a pivot converts linear motion to angular motion within the instrument. Similar restraint mechanisms are used, this time acting about the pivot. Although modifications of the simple pendulum are widely used, the pendulum and its instrumentation are not as well understood as the linear accelerometer.

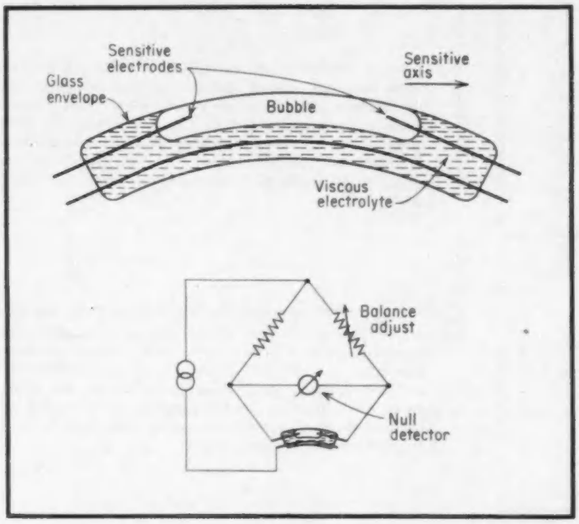
The most sensitive accelerometers in the world are the gravimeters used in geodetic measurements of the earth's gravity field. Here sensitivities of one 10-millionth of the value of g are common, though rarely exceeded. Navigational accelerometers seldom display sensitivities even one-hundredth as good, while linearity is at least another order of magnitude poorer again. But navigational accelerometers cover a range of about 100,000 to 1, while gravimeters have a range of about 100 to 1. Thus the ultimate performance of accelerometers in general involves a tradeoff between sensitivity and linearity on one hand and range on the other.



1 SIMPLE PENDULUM points to or oscillates about the net acceleration vector, indicating direction of acceleration but not magnitude. Where horizontal acceleration only is to be measured, the tilt of the pendulum is significant since this tilt angle is related to the ratio of horizontal acceleration to gravity. Thus, gravity provides a calibrated spring restraint for measuring horizontal acceleration, but the direction of gravity must be remembered if the tilt angle is to be measured. Viscous damping is commonly used.

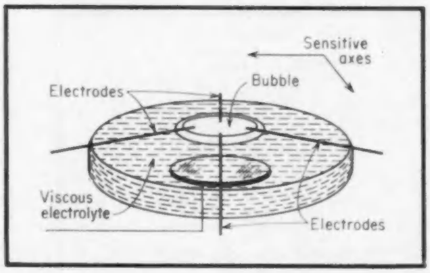
2 COMPOUND PENDULUM differs from the simple pendulum only in having a different unbalance-mass to inertia ratio. The common instrumentation shown uses a feedback torquer amplifier to supply the spring restraint. This effective spring is so stiff that only small displacements occur and cross-coupling spring effects such as gravity are all but negligible. A flotation fluid minimizes pivot loading and also supplies damping adequate to make the float inertia term negligible and instrument response essentially first order. At the same time the damping coefficient to spring restraint time constant is small enough for present day vertical tracking systems. High precision requirements call for the viscous restraint to be Newtonian in character and nonvarying in time.

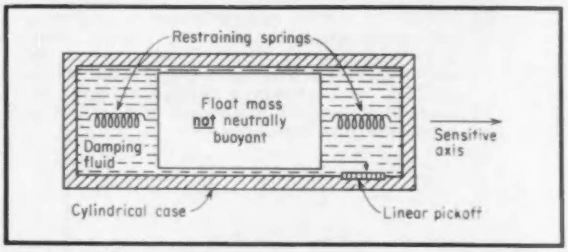




3 **SINGLE AXIS BUBBLE LEVELS** can detect tilt angles of a minute of arc or less. Gravity plays the same role as in the simple pendulum, while damping depends on liquid viscosity. Inertia effects are negligible. The liquid used is an electrolyte, and varying interelectrode conductances depend on the relative lengths of electrode uncovered by the liquid. A three-terminal network serves as two legs of a Wheatstone bridge, and a galvanometer null indicates verticality of the bubble vial. Current unbalance near null is an indication of horizontal acceleration.

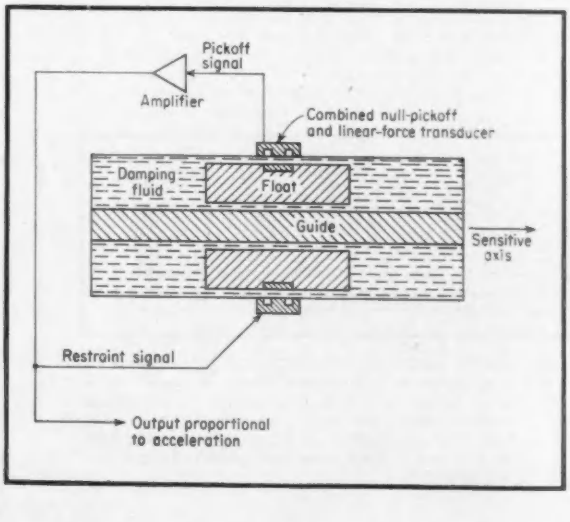
4 **CIRCULAR BUBBLE LEVELS** are sensitive to horizontal accelerations in two directions but are not as linear as the single axis type. Both single axis and circular bubble levels require a known acceleration bias such as gravity and must remember the direction of gravity. This memory is provided by gyroscopes in all devices that are carried in moving vehicles.

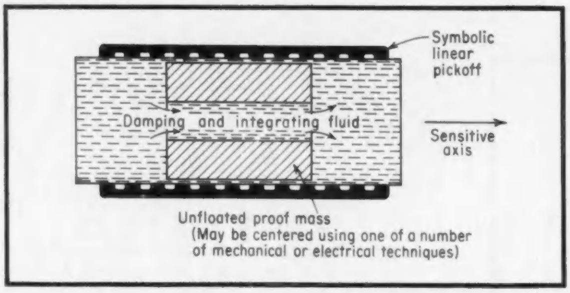




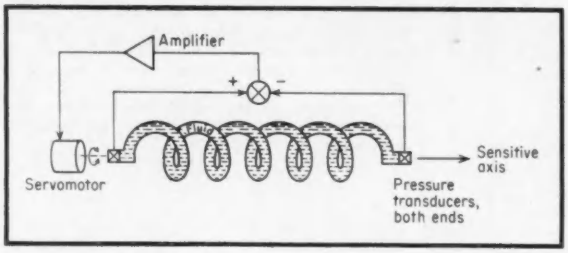
5 **LINEAR CYLINDRICAL ACCELEROMETER** with spring restraint has a displacement proportional to acceleration. The spring constant provides calibration, and the signal generator is usually one of a variety of forms of E-pickoff. Often partial flotation is obtained by immersing the proof mass in a damping fluid.

6 **LINEAR CYLINDRICAL ACCELEROMETER** in a different form uses a linear thrust motor acting in a servo loop to keep the pickoff at null. Acceleration is then proportional to some function of the excitation current supplied to the motor. Linearity is almost entirely dependent on the linearity of the thrust motor. The alignment rod restricts sideways motion of the proof mass.



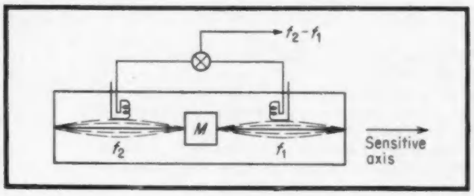


7 **LINEAR CYLINDRICAL ACCELEROMETER** in still another form uses the viscous restraint of the damping fluid to balance the force of acceleration. This process leads to integration, and devices of this type are often referred to as velocity meters. A linearly calibrated or corrected pickoff running the full length of the proof mass' freedom is necessary for precision instrumentation.

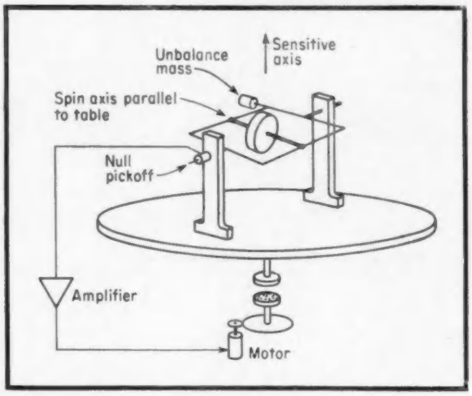


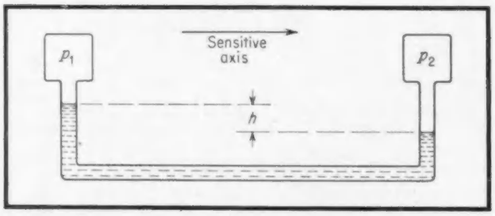
8 **HYDROSTATIC SPIRAL TUBE ACCELEROMETER** depends on angular acceleration to null the pressure difference between opposite ends of the tube. Linear acceleration along the spin axis creates the pressure difference, and the angular acceleration imparted by the servomotor nulls it out. Motor speed is proportional to instrument velocity, and the number of revolutions is proportional to distance traveled.

9 **VIBRATING STRING ACCELEROMETER** is sensitive to accelerations along the string axis. Tension differences result, and the natural frequencies of the two supporting strings vary accordingly. Even though elaborate instrumentation is required to obtain insensitivity to cross-axis accelerations, high caliber accelerometers have been constructed.



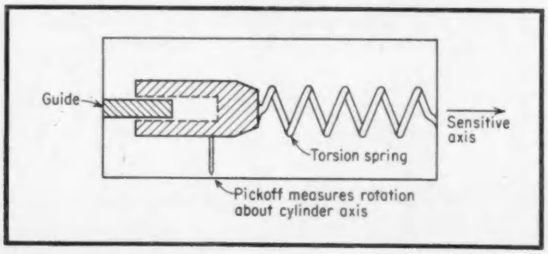
10 **ONE-DEGREE-OF-FREEDOM PENDULUM** uses gyroscopic torque to null the torque generated by linear acceleration. Instrument rotation about the table axis forces the gyro to precess, resulting in a torque about the pendulum pivot axis. A high gain amplifier drives the motor at a speed proportional to the deviation signal from the pickoff on the pendulum pivot axis. The integrating property of the gyro makes it possible to measure velocity with this instrument. Changes in velocity are proportional to turntable displacement.

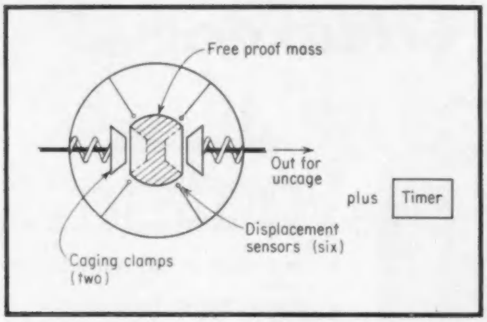




11 **SIMPLE GAS PRESSURE ACCELEROMETER** depends on acceleration of a horizontal column of liquid. As in a pendulum, this instrument is sensitive to accelerations normal to the gravity field. No integration is provided with this arrangement, although manipulating pressures P_1 and P_2 could conceivably modify the operation of this device.

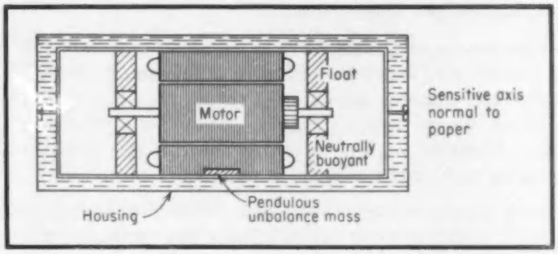
12 **TORSION PENDULUM** modified to be insensitive to lateral accelerations is another form of linear accelerometer. Rotation of the pendulous mass rather than its translatory motion is the basic measured output.

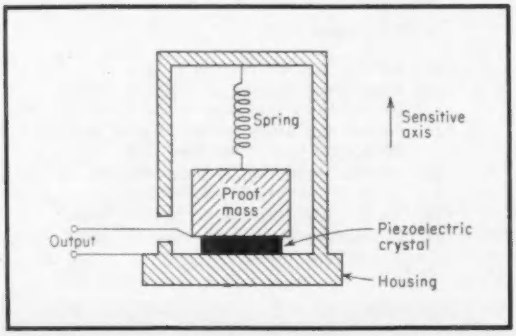




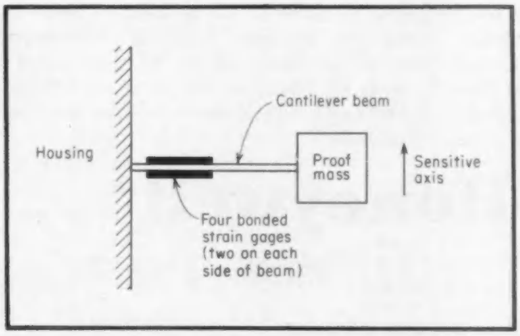
13 TRANSIT-TIME ACCELEROMETER measures the time interval between release of a free-falling proof mass and its contact with the containing cavity. Thereafter it is recaged and rereleased and another interval or transit time measured: only periodic acceleration measurements are possible. Assuming constant acceleration through an interval, acceleration is proportional to the inverse square of the time interval. The actual measured quantity is the change in velocity during an interval. A possible continuous scheme might use multiple and overlapping measurements.

14 DOUBLE-INTEGRATING ACCELEROMETER, also known as the distance meter, uses the inertia reaction of an electrically driven rotor to balance the torque of a pendulum. The rotor is enclosed within an unbalanced but floated cylinder. Bearing friction is overcome by the electric drive while speed changes alone react, through the motor, against the float. The speed changes are a measure of changes in linear displacement.

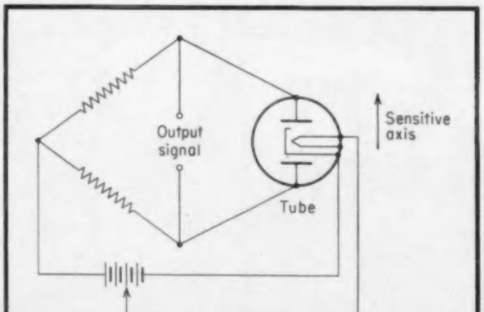




15 SELF-GENERATING ACCELEROMETER uses piezoelectric crystal in compression to self-generate an output voltage proportional to acceleration. In the spring-mass system consisting of a weight pressed against the top of the crystal, a highly compressed soft spring reduces creep instability. Linearity is good over a wide range of accelerations.



16 CANTILEVER BEAM ACCELEROMETER has four strain gages bonded to the beam and is sensitive to acceleration perpendicular to the beam in the bending plane of the beam. Gages are connected as four legs of a Wheatstone bridge, yielding an output proportional to acceleration. In actual instruments the housing containing the beam and proof mass is often filled with a damping fluid. Piezoelectric elements such as barium titanate can be bonded to the beam as well as conventional wire strain gages.



17 VACUUM TUBE ACCELEROMETER uses special tube in which two flexible plates deflect under acceleration forces. This is a special case of the cantilever beam accelerometer. The current output of the bridge is directly proportional to tube acceleration.

Safe, Reliable Process Monitoring

Part II: SELECTION, DESIGN, and SPECIFICATION

THE GIST: Continuous and data-sampling systems comprise the two major types of process monitors, as described by the author in Part I (December 1960). Besides reviewing system functions and operation, the first part also explains what can go wrong with typical transducers and monitor circuits to reduce systems reliability.

However, as detailed here, positive steps can be taken to improve over-all monitoring reliability. Among them are the selection of proven transducers and arrangement of a system configuration that includes failsafe circuits and logic testing. Such information must be included in the systems specification, a document that incorporates customer experience in a way that guides the vendors to produce a safe, reliable monitoring system.

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Maximum reliability for process monitoring systems such as those watchdogging critical processes like nuclear reactors and chemical operations can be assured by taking advantage of both customer experience and vendor experience. Customer experience is reflected in the preparation of judicious system specifications that interrelate the reliability requirements of the process and its monitoring system. Besides including the over-all design philosophy for the monitoring system, typical specifications contain some statements regarding the minimum experience required of the vendor to assure the customer that the system will meet requirements.

Preparing monitoring system specifications

The first step is for the customer to define the monitoring system requirements adequately and realistically. The specifier must force system design to be in the most reliable configuration and his specification will result in its achievement. The reliability requirements for an ideal continuous monitoring system would, for example, allow a maximum of one to five false trips (or scrams) per year due to a failsafe operation or malfunction of the process safety monitoring equipment. Scheduled calibration at six months or shorter intervals for each controller would be reasonable.

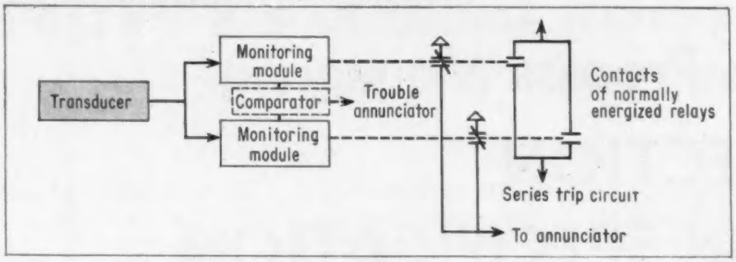
The desired reliability for data sampling (or data acquisition) systems is more stringent. One to two thousand hours of on-line operation is required between scheduled shutdowns, with only one unscheduled maintenance shutdown permitted for each ten periods of on-line operation.

Experience with installed monitoring systems indicates that such ideal reliability requirements have not yet been met. Operating results on two large continuous temperature monitoring systems show that the number of false trips is about ten times too great. Intermittent wiring faults in the monitor and failures of transducer connections and the output logic modules caused most false trips. On smaller, newer continuous monitoring systems a few primary-function false trips have occurred from sensitive relay failures. But magnetic-amplifier circuits have accumulated between 10 and 15 million unit-hours per detected malfunction (for a 1,000 point system about 1.5-2 years operation per failure).

Consider the transducer

The second step is to specify reliable transducer type and configuration. Here, the reliability of the transducer itself in measuring the particular process parameter, and the power gain needed after the transducer to carry out the desired function, become significant. A transducer with a large power output immediately enhances system reliability by requiring minimum gains, which, in turn, reduces the number and complexity of the components.

(A) Single transducer, dual module



(B) Dual transducer, dual module

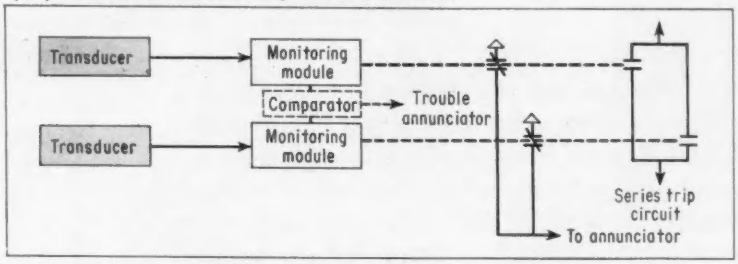


FIG. 1. When the transducer has been proven by experience to be highly reliable, only one (per point) need be used, A. But when utmost confidence cannot be placed in the transducer, two are used for reliability enhancement, B.

High output also improves the signal-to-noise ratio.

As an example of the difficulty of obtaining a reliable temperature measuring element for monitoring a nuclear reactor, five designs were needed to evolve an acceptable resistance temperature detector. Each successive configuration, except the third, which was a regression, resulted in doubling transducer life. The second and fourth configurations were successive replacements for about 7,000 units. The fifth configuration is now considered to be an adequately reliable transducer. For every 100 units, field experience shows that 90 to 95 are expected to survive 10 years of critical service operation.

The third major step in the preparation of monitoring system specifications, besides defining system requirements and specifying the transducer, is the exercising of good engineering judgment. The designer must not only specify system configuration—a point dealt with in more detail later—but also must take advance measures precluding undesirable or marginal techniques or components that may reduce monitoring reliability. For example the specifications may outlaw such configurations as a series string of magnetic amplifier control windings which, without sufficient buffering, can interact and cause totally unacceptable performance.

Anticipate vendor performance

To produce reliable equipment the vendor must of course be experienced in circuit design and manufacturing operations. But the user's specification can add safeguards in the specification by including statements that further assure adequate vendor performance by requiring adequate experience. Such statements as those below are paraphrased from actual specifications. They have evolved from the evaluation of presently installed equipment.

The system specified herein will be incorporated as part of the protective system of a nuclear process. Detected failure of the equipment requires process shutdown. Undetected failures or malfunctions may allow damage of a serious nature to the process. Therefore it is required that the equipment specified be extremely reliable.

To insure reliability, the specified system must be composed of components, modules, etc., which are a normal product of the seller and are in continuous production. All components, circuits, and techniques employed in the system must have been applied extensively so that the reliability of the components and techniques can be substantiated by the seller. Specifically excluded are components, circuits and techniques available in limited of prototype quantities or tested only in breadboard or development equipment.

The seller must employ completely designed and proven components from which to assemble the system. Here, proven components are at least second generation and preferably third generation as defined below:

***First generation*—Successful application of production components, modules, etc., in the field to a system with functional requirements similar to those specified.**

***Second generation*—Successful field application of production components, modules, etc., incorporating changes or design improvements found to be necessary by field application of first generation units; or two years successful application of large quantities of first generation devices not requiring revision.**

***Third generation*—Successful field application of production components, modules, etc., incorporating changes or improvements found to be necessary or *desirable* by field application of second generation units.**

To be considered as a successive generation, equipment must utilize essentially the same circuit design, components, and layout as the previous generation. For instance, the following design or circuit improvements are *not* considered as successive generations: the transition from vacuum tube to semiconductor design, from standard cell reference to Zener diode reference, from capacitor coupling to diode coupling, and from point-to-point wiring to etched or printed circuitry.

Reliabiltiy depends on system configuration

In determining system configuration for maximum reliability of safety monitoring and continuity of process operation, system functions are separated into:

1) Primary functions like high-limit and low-limit functions that protect the process, and

2) Secondary functions like approach-to-trip and visual readout of process parameters that are used for process operating information.

Then the specifications must call for an equipment arrangement such that the secondary functions cannot interfere with the primary functions. In a continuous monitoring system, function isolation can be accomplished by a buffer module, for instance, separating an approach trip module from a data logger (see Figure 3, Part I, December 1960).

Continuous monitoring systems

When the transducer's proven reliability is several orders of magnitude greater than that of the electronic monitoring equipment, and when adequate power is available from the transducer, a single transducer feeding parallel redundant monitoring modules should be considered, Figure 1A. Here, actuation of the series trip circuit initiates a process shutdown sequence. A false trip due to failsafe failure of one redundant channel is prevented because the normally energized relay coils hold the parallel set of relay contacts closed.

For a true process alarm or transducer failure, the relay associated with each monitoring channel will de-energize and its contacts will open. Then, since both parallel contact sets are open, the series trip circuit becomes operative. However, if one channel fails safe its corresponding set of contacts opens but the other contacts remain closed, thereby not initiating a scram. Any noncoincidence between channels as detected by the comparator operates a trouble annunciator. The redundant channels must be highly failsafe, for otherwise, if one channel is inoperative due to a non-failsafe failure, an unsafe process condition will not result in a trip.

When transducer reliability and monitoring equipment reliability are about the same and process operation demands extreme over-all system reliability, a completely redundant system must be considered, Figure 1B. Here, the transducers and the monitoring circuits are duplicated. Again, highly failsafe circuits are mandatory. The comparator detects when both channels are not in agreement. Because certain transducer types do not fail safe, they will not produce a trip when warranted and, for ultimate process safety, any detected nonagreement must necessarily shut down the process.

Triple redundancy—two out of three channel trips required to produce a safety trip—allows any one of three channels to fail safe or unsafe without jeopardizing or affecting either process safety or continuity. By good equipment design, it is extremely improbable that two non-failsafe or failsafe failures will occur at the same time. However, while a triple redundant configuration is beneficial for highly reliable small systems that must always operate safely, such as for reactor flux level monitoring, it approaches economic impossibility for large continuous monitoring systems.

Data sampling systems

Data sampling systems—discontinuous in operation—can achieve all the required process monitoring functions plus additional ones at equal or less cost than a continuous system—provided the number of monitored points is large. Data sampling monitors offer a much higher degree of inherent safety monitoring reliability than do continuous systems by emphasizing self-test logic rather than failsafe design. Furthermore, almost all the advantages of a continuous system's dual-transducer-circuit redundant configuration can be obtained by the proper functional design of a single transducer data acquisition system; and the reliability of a continuous triple redundant system can be almost obtained from a dual-tranducer-circuit data acquisition system. Most additional logical steps insuring reliability are the same in either the single or dual transducer configuration of the data acquisition system.

The logical steps are essentially an automatic test program incorporated as part of the monitoring system. For example, the data acquisition system, Figure 2, tests all functions (except the multiplexer) as often as required by injecting two consecutive standard signals of different magnitudes into the data

Reliability by logic

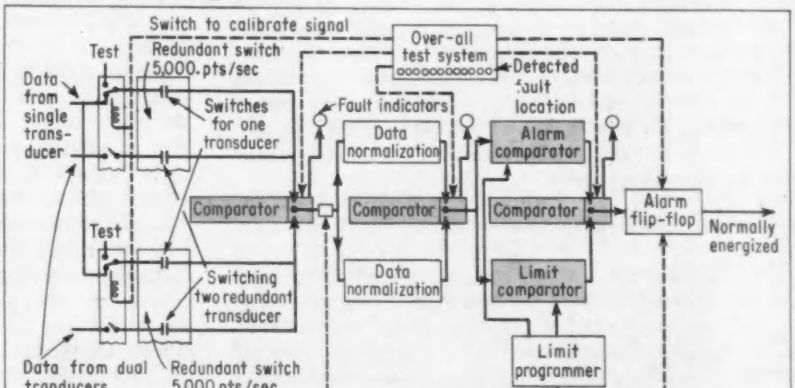


FIG. 2. In data sampling systems, avoidance of inadvertent process shutdowns from monitor equipment failure is obtained by a program that tests for failures and automatically replaces failed logic elements of the system.

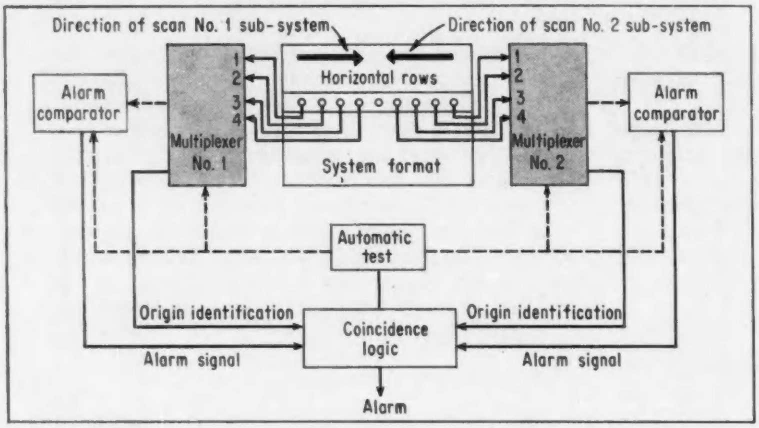


FIG. 3. Probably one of the most reliable arrangements is to use two similar subsystems, each scanning the same point and using logic on the coincidence or noncoincidence of individual signals.

normalization stage and injecting a standard program into each comparator.

Using testing logic

The first standard signal should be sufficient to cause all comparator circuits to trip. The trip signal should in turn activate the alarm circuits. These circuits are time-delayed flip-flops, with a signal from the test programmer resetting the flip-flop before the delay period ends. However, if due to some malfunction the trip signal does not arrive at the comparator, the signal from the programmer causes the alarm flip-flop to go into the alarm state. The alarm signal in turn can either actuate additional testing logic or cause a process shutdown.

The second standard signal is less than the programmed test limit and normally should not cause the comparators to signal an alarm condition. If any malfunction exists in a functional block, an alarm will originate in one or more comparators to cause process shutdown or additional logical testing.

However, since the object is to prevent process shutdown due to monitoring equipment failure, more than likely the design will call for additional logic testing prior to initiating shutdown. When the second standard signal does initiate an equipment alarm for a particular process variable, a second over-all test programmer then checks each functional block for abnormality.

Multiplexer logic tests

The concept of monitoring system self-test is relatively straightforward because a fixed magnitude signal can be injected at the data normalization block. However, checking multiplexers is more difficult since there is a wide difference in transducer outputs monitoring the same process parameter.

Even so, any one of several logic tests can be applied to multiplexer switches to prove their reliability, the particular test depending on the known failure mode of the input switches. If the switches can be guaranteed to fail open circuit (which is unlikely), or if the failure is due to nonoperation, a standby redundant switch can be connected in parallel when the comparator detects *no signal*. The system will then operate with the second switch unless it too indicates *no signal*, in which case the process will be shut down.

However, because of the devious nature of most multiplexer failures, a more complete and expensive form of multiplexer testing will most likely be required to insure adequate over-all reliability. The degree of complexity depends on the known reliability record of the multiplexer switch and its associated driving and gating circuits. The most complex testing mode is that of periodically transferring the multiplexer switch (or groups of switches) to a separate test circuit to weed out any failed or marginal units in a redundant pair. Such a testing program would have to be based on the proven fact that a failure in the remaining element of the redundant pair would be improbable before the next test period.

Reliability by system redundancy

The reliability of a single transducer configuration data sampling system can be improved considerably by employing the scheme shown in Figure 3. Here, two almost independent subsystems share the same transducers and terminal board. Each subsystem incorporates the same self-test logic as for the single transducer data acquisition system just described. Each independent subsystem scans the same row of data in the format from opposite sides. Thus each transducer is scanned twice, but at different times in the scanning cycle. Such a procedure therefore requires remembering the origin of a trip signal from each subsystem and comparing it with the origin of the signal from the other subsystem. The trip-origin storage needed is not too great because only one row at a time is checked.

Coincidence of trips from the same format point initiates process shutdown. A noncoincident trip calls for further automatic testing. If the subsystem indicating an alarm tests good and the second subsystem (not agreeing) tests bad, the true alarm situation is verified and an alarm is initiated requiring process shutdown. If the opposite is found to be true, shutdown is not initiated. This configuration has one outstanding feature: a malfunction of one system does not require process shutdown, since in the event of one complete system failure the process may still be monitored by the remaining system.

Which Teletype printer is best for you?

Which of these Teletype Model 28 page printers is best for your message and data communications needs? Each will perform the basic function of all Teletype equipment—to flash information over long or short distances. But in addition, each has varying capabilities to meet the requirements of the individual user:

Send-receive page printer in console—probably Teletype's most familiar product; for sending as well as receiving page copy.

Receive-only page printer in console—the same machine, but without a keyboard. For use where information need only be received, not sent. No operator is required.

Table model—with or without keyboard . . . similar model available for rack mounting.

Combination set—a complete message center in one compact cabinet. In addition to page printer and keyboard, it contains facilities for preparing punched tape and for transmitting and receiving via tape.

All of these Teletype Model 28 page printers feature the Stunt Box, a built-in "programming" mechanism that will inexpensively handle a wide variety of remote control and switching tasks such as automatic station selection. All models can be supplied with sprocket-feed and tabulating mechanisms for use with multi-copy business forms. All are available, too, in a choice of colors to match office decor.

Teletype Corporation manufactures this equipment for the Bell System and others who require the utmost reliability from their data communications. Teletype equipment can be used with Data-Phone and other communications services.

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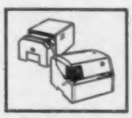
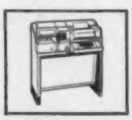
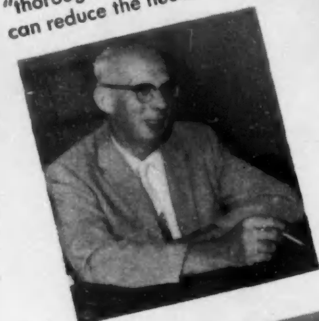

Tape Reader and Typing Tape Punch

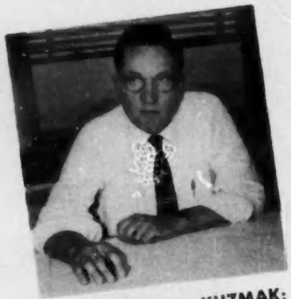

Send-Receive Page Printer


Automatic Send-Receive Set

Free Model 28 Line folder. Write Dept. 21-B, 5555 Touhy Avenue, Skokie, Illinois

HOUGHTON'S EISMANN: "thorough housekeeping can reduce the need."





NEW BRITAIN'S KUZMAK: ". . . need a universal system . . ."

FIA's BARRITT: ". . . loss reduced from $30,000 to $2,000 . . ."

P&WA's KIRKMAN: "use them wherever they're needed."

What Industry Thinks of Fire-Resistant Fluids

STEPHEN S. LIVERS
Control Engineering

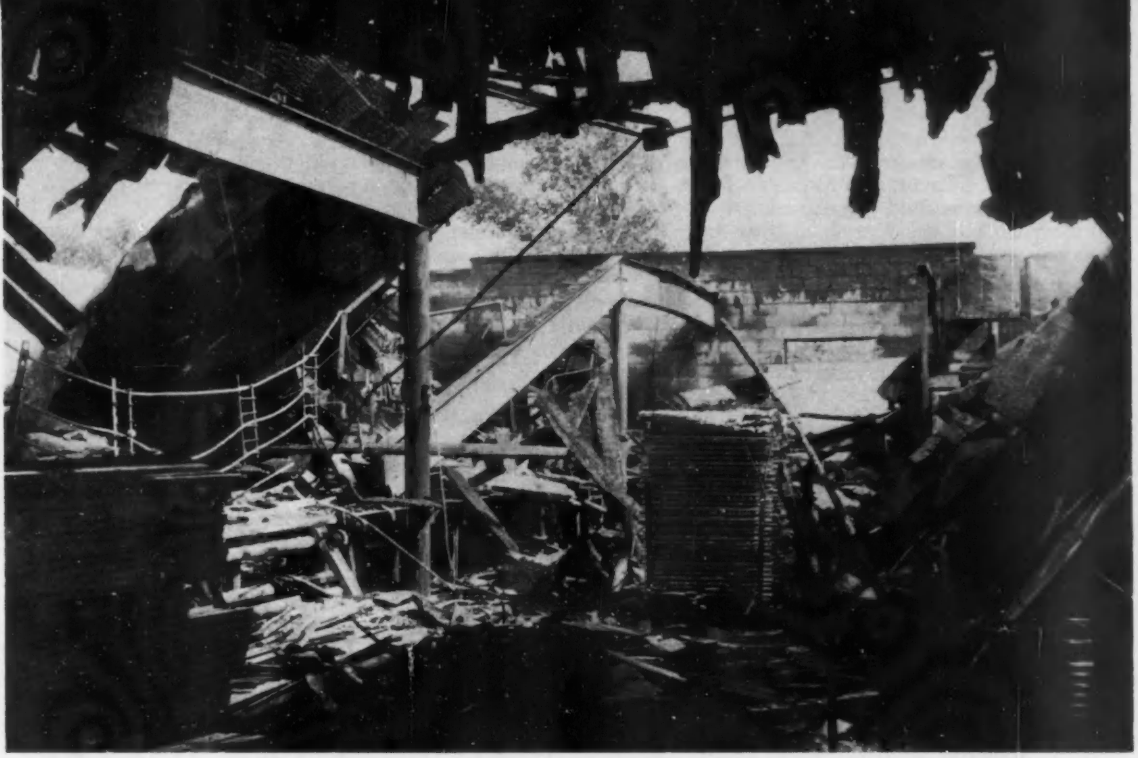
New fluids for industrial hydraulic systems that are less dangerous when exposed to common fire hazards have received increased interest—and application—in recent years. But problems—such as cost and component compatibility—complicate their use. To find out what these problems are, how these fire-resistant fluids have been applied, and why they're worth the trouble, Control Engineering surveyed experts in the hydraulics field and at insurance companies. This first comprehensive report on the subject gives the results of the survey.

The ruined aluminum extruding plant shown on the opposite page was devastated by fire—a fire spread by flammable hydraulic fluid used in the plant's machinery. This loss could have been substantially reduced if the factory's hydraulic system-equipped machinery had used a fire-resistant fluid. Why have these fluids not been applied everywhere there is a fire hazard; and on the other hand, why have manufacturers with large investments in other fire safety measures—sprinklers, plant fire departments, etc.—taken the extra step of using these more troublesome fluids? In order to find the answers to these questions—and others—CONTROL ENGINEERING editors and McGraw-Hill Newsmen surveyed expert fluid makers, system designers, machinery builders, machinery users, and fire insurance underwriters.

Fluid properties

Manufacturers of hydraulic fluids wax enthusiastic over the virtues of their fire-resistant products and tend to downgrade the importance of the fluids' shortcomings. Hydraulic system and machinery builders take the opposite tack: they seize upon the serious weaknesses of fire-resistant fluids and accept their strong points with the grudging praise that, after all, they're still not as good as petroleum-base types. In general they passively resist work with the fire-resistant systems because it's more trouble and they often honestly believe that fire safety can be obtained by other measures. They insist that fires shouldn't be blamed on the fluids. But many users have learned to live with the new fluids. If they or their insurance companies feel the added protection of the less hazardous fluids is needed, the users are willing to put up with them. Specifically, here's how opinion breaks down on the more salient factors.

• **Flammability**—The most important feature of fire-resistant fluids is happily not obscured by controversy. There is no disagreement that water-glycols (see table, p. 118) are the least flammable. Next, it is agreed, are the phosphate esters (most widely used of the straight synthetics). The difference between these two is not great, but it is distinct. Far down the scale of fire safety are the oil and water emulsions. Standard petroleum-base oils are at the bottom of the list, separated on the flammability scale from the emulsions by almost as



An aluminum extruding plant, completely destroyed by a fire spread by non-fire-resistant fluid.

much as are the latter from the phosphate esters. It should be noted that none of the *fire-resistant* fluids is *fire safe* or *nonflammable*. In fact some experts prefer the term *less hazardous*. These measures of fire safety include not only determination of standard flash and fire points and autoignition temperatures but also the especially applicable condition of rupture of high pressure fluid lines. In this case finely atomized fluid is sprayed onto a hot surface or into an open flame, a situation that has caused many fires.

• **Viscosity**–The fire-resistant fluids are available in a range of viscosity grades to meet user needs.

• **Oxidation and deposit formation**–Here the fire-resistant types are probably better than those made of petroleum, although the emulsions, since they contain oil, are not so resistant to oxidation as the other two types. At the end of three and a half years' use by Pratt & Whitney Aircraft Div. of United Aircraft Corp., as reported by Clifford Hayden of the plant's Master Mechanic's office, very good service was obtained from both water-glycols and phosphate esters. For the latter P&WA has found only trace amounts of sediments with hardly even a change of color. The water-glycols have been no problem on this score at all.

• **Lubricity**–The phosphate esters have a lubricity that closely approaches that of mineral oil, and this accounts partially for their more widespread use over the water-base types. The emulsions are not so good as either of these. But P&WA's Hayden has had no failures on any of his 38 machines, 17 of which use water-glycol fluid. Even so, experts at four hydraulic system manufacturers favored phosphate ester fluids for their edge in this characteristic. These were Ellis Born, manager of engineering for Denison Engineering Div. of American Brake Shoe Co.; Walter Kudlaty, chief design engineer of Flick-Reedy Corp.; Martin Englebretson, The Oilgear Corp.; and Robert Rynders, Racine Hydraulics and Machinery Co., who is also chairman of the fluids group of the National Fluid Power Association. Also in agreement on this was Leonard Lindner, chief engineer of Hydraulic Press Manufacturing Co.

• **Demulsibility**–There have been few problems reported along this line.

• **Foaming resistance**–Any problems that arise due to foaming can be solved by the addition of antifoaming agents by either the fluid manufacturer or the user. This is the same situation as for mineral oils.

• **Compatibility**–This seems to be the biggest bugaboo in the fluids picture. As John Kirkman of Pratt & Whitney Aircraft's Health and Safety Section put it, most of these fluids are "darn good paint removers". In addition, some of the fire-resistant fluids are not compatible with a host of standard seals, packings, and other components developed for petroleum fluids. In some cases these limitations have been enough to discourage a potential user from using these fluids at all.

For instance, the New Britain-Gridley Div. of New Britain Machine Co. has received several specifications from its customers that requested that machines be equipped with a hydraulic system designed around a fire-resistant fluid. So far New Britain has been able to keep its customers happy without building any such machines. Paul Kuzmak, manager of New Britain's Machine Design Dept. cites the compatibility problem as the primary deterrent. Kuzmak recalled that within the past year, in order to try to meet a customer specification, he attempted to find a paint manufacturer who would guarantee that his product would be impervious to all types of fire-resistant fluids. Some offered such performance but would not stand behind it with a guarantee. Kuzmak's problem: since he can't be sure just how his machines will be used, he hesitates building

a machine that can be used with only one type of fluid. And since different manufacturer's fluids often vary within the same fluid type, he might even find himself specifying one brand of fluid—something he refuses to do.

So far Kuzmak has been able to defer getting involved with these fluids since New Britain's machines—metal cutting equipment—do not have the inherent fire hazard of other machinery, such as hot formers, automatic welders, etc. But when users become insistent on more widespread fire protection—and this seems to be the trend—he's going to need help from fluid and component manufacturers if he's to stick to his "universal" fluid requirement.

On an individual fluid basis, though, there are paints and components to fit all requirements. According to E. F. Houghton & Co.'s manager of lubrication sales, William Eismann, here is a rundown of compatible products for each type of fluid based on the assumption that all brands of each type can be considered similar.

Emulsions: Generally compatible with all seals, packings, etc. that are usable with straight oils. Require special paints.

Phosphate esters: Attack most paints: epoxy resin paint is generally resistant; no paint at all is best answer. Require special seals, usually butyl rubber.

Water-glycols: Some paint needs as for phosphate esters. Compatible with most rubber seals and packings, less so with leather, and no good at all with cork. Cannot use diatomaceous earth filters. Are not compatible with zinc or cadmium; aluminum usually must be anodized.

• **Compressibility**—While Jack Russ of Union Carbide Chemicals Corp. asserts that the water-glycol fluid, his company's product, has as good a characteristic for compressibility as any fire-resistant type, Lewis S. Stone of Monsanto Chemical Co. claims that compressibility effects are nil with Monsanto's synthetics. Among the users, Denison's Born favors the phosphate esters for their freedom from these effects; P&WA's Hayden has had no trouble on this score with either fluid.

• **System pressures**—In general the hydraulic system designers place no limitations on their systems when the fire-resistant fluids are used. Full warranty is given by Denison when phosphate ester fluids are used, and standard pressures can be used in low pressure units (up to 1,000 psi) and in some intermediate pressure units (1,000-2,500 psi). Pressures must be limited in some of Denison's vane-type equipment. Oilgear finds that its systems can operate at up to 2,500 psi with fire-resistant fluids. Flick-Reedy places no limitation on system pressures. Racine allows identical pressures to be used with petroleum and less hazardous fluids as long as seals meet the latter's requirements.

• **Toxicity and odor**—It seems that most fears of serious effects in this area are virtually groundless. Pratt & Whitney Aircraft's experience and practice with two fluids seem worth covering. According to safety man Kirkman, the fluids are rough on the eyes and irritate the skin. They are also unpleasant to inhale, so P&WA uses plenty of ventilation during handling. Hayden believes the phosphate esters slightly more toxic, but there have been no serious problems since protective items like goggles, aprons, and hand creams are used in fluid handling. A big factor is that the same crews, experienced in handling the fluids, are always used.

• **Price**—Emulsion fluids at \$1.25/gal are about twice as expensive as petroleum (\$0.50/gal). Water-glycol fluids are almost four times as expensive as standard fluids, selling for about \$2.25/gal. Phosphate esters command the highest price: \$3.25-3.50/gal. Pratt & Whitney Aircraft changed some of its complement of fire-resistant fluid-equipped machines to water-glycol in part because it could save \$1.40 a gallon; the additional fire protection was the other factor in the conversion. But with either fluid P&WA is careful not to waste a drop in handling: and it reclaims the fluid on its own equipment when it must be drained. Monsanto, while it notes the initial higher price of the synthetics, claims that the fluids' inherent stability makes their use economical.

TYPES OF FIRE-RESISTANT FLUIDS

SYNTHETICS
Phosphate esters—Most widely used
Halogenated hydrocarbons (usually chlorine compounds)—Not yet widely used
Mixtures of the above two—Very limited use

WATER BASE FLUIDS
Water-glycols—Next most popular to phosphate esters

WATER-OIL EMULSIONS
Oil in water—Water supplies main fire resistance
Water in oil—Newly developed for low cost applications such as coal mining. Generally not included in references to emulsions in text

What's the magnitude of the effort?

In the hydraulics industry only the fluid manufacturers are pushing the use of the fire-resistant fluids. The system and component builders and the machinery makers would rather not be bothered. Makers of only fire-resistant fluids, like Monsanto and Union Carbide, are naturally the biggest boosters, but both sell good maintenance, too. Carbide points out the safety advantage to be had through good maintenance—possibly reducing the quantity of the more expensive fluid used if it is adopted. Houghton, which makes petroleum fluids along with all fire-resistant types, as well as compatible seals and packings, also stresses good housekeeping.

Fire-resistant fluids are still not used in great quantities, considering the sales efforts of the fluid makers and the urging of insurance firms, labor groups, etc. Monsanto estimates the total use by industry of all types amounts to only 3 percent of total fluid consumption. Houghton figures its fire-resistant fluid sales at about 75 percent of its hydraulic fluid total, but the firm does not make any very inexpensive fluids so it does not have a full line on which to base its figures.

Industries that have been the quickest to apply the less hazardous fluids are ones in which there are inherent fire hazards, as contrasted with the attendant hazard of outside sources of ignition coming in contact with open pools of leaked fluid. The latter situation prevails in the metal cutting field, where simple housekeeping and good maintenance can eliminate many hazards. Also in metal cutting, pressures are not usually great enough to yield the risky atomized spray that results

from a ruptured line in a high pressure machine. For this reason Warner & Swasey Co. sees no need to manufacture its machines with fire-resistant systems. But hot metal molding, die casting, and automatic welding machine users have been among the first to use the fire resistant fluids. For example, 59.3 percent of the companies surveyed by *Precision Metal Molding* magazine in 1959 used fire-resistant fluids, though not necessarily exclusively.

The hydraulic system designers have responded to the development of the new fluids (and the fluid companies are continuing in this development—enough to keep the component makers quite active) with development programs of varying size. With sales for fire-resistant fluid systems an important part of his company's total volume, Richard Leslie of Vickers, Inc., describes the development of systems and components for these fluids as accounting for "a great deal" of the firm's total effort. At Denison, where the estimates include defense sales and development figures, the next year is expected to show systems for fire-resistant fluids accounting for about one-fourth of total sales; approximately one-half of the company's R & D is now absorbed in work with these systems. Systems designed for the less hazardous fluids are not yet a large part of Racine's sales. In the past six to eight years development work on these systems at Racine has accounted for about 10 percent of total R & D investment. Flick-Reedy makes only components, not systems, and many of these components can be used equally well with any type of fluid. Therefore the company's development effort for fire-resistant fluid components has been modest.

Among the big users of the fire-resistant fluids are automotive and aircraft industry manufacturers who include among their operations hot metal forming, automatic welding, die casting, and other potentially hazardous setups. Also these companies are big firms, and these tend to be the first users. Both the Ford Motor Co. and General Motors Corp. make it a practice to specify fire-resistant fluid systems on hydraulic machines when the equipment is to be used in or near hazardous environments, such as close to furnaces, ovens, heat treating operations, etc. All die casting, injection molding, and many welding machines are specified this way. Pratt & Whitney Aircraft has converted to fire-resistant fluids all presses, lift trucks, etc. that operate near heat treating equipment. Equipment near other sources of ignition, like motors with exposed brushes or where there is danger of short circuits, are recommended by Carbide's Russ as good applications.

Converting older systems

Pratt & Whitney Aircraft estimates that it took about 50 hours to convert one of its 50-ton presses to fire-resistant fluid; a 3,000-ton press took about 250 hours. Included in this chore was draining and cleaning the equipment and removing the paint; seals and packings were changed. The reconversion to water-glycols from phosphate esters took only three or four hours. P&WA did not again change packings. Houghton advises that in the original conversion static seals usually do not have to be changed until a need arises for a complete teardown; but dynamic seals must be converted. Ford and GM do not call the conversion difficult but note that care must be taken to clean the system thoroughly and change all necessary seals.

Denison, however, calls field conversion very difficult, and Oilgear, Flick-Reedy, and Racine agree.

The payoff—the insurance companies' stand

Just how good are the less hazardous fluids in preventing or at least reducing the severity of industrial fires? Insurance companies' records show strong justification for undergoing the difficulties in applying these fluids that are described above. Jack Barritt, engineer for the Factory Insurance Association, reveals that his group has experienced no really bad losses from hydraulic fires since 1954. Though he quotes no current specific loss figures, he is aware that there have been some fires, however. He recalls one insured company which had a large fire as the result of the use of non-fire-resistant fluids; the total loss was $30,000. The FIA recommended that the insured convert to the less hazardous type. A similar failure occurred again; there was no fire, and the total loss was $2,000. It should be noted, however, that FIA-insured companies are among the biggest industrial firms. These companies tend to be very "fire conscious"; and since they must qualify for FIA's insurance (only preferred risks), they have sprinkler protection and plant fire departments and use other advanced fire protection systems. The experience cited above and others have shown that fire-resistant fluids are important in preventing fire losses and interruptions in production. Failure to use a fire-resistant fluid is sufficient cause in itself for FIA's recommending automatic sprinkler protection for an area, whether other combustibles are present or not.

The FIA's counterpart among the mutual companies (FIA is an association of stock insurance companies) is the Associated Factory Mutual Insurance Companies (made up of mutual firms). The Factory Mutuals organization maintains an Engineering Div. with a $7 million annual budget and 840 personnel. This division conducts what is probably the largest independent test program on fire-resistant fluids. It has tested and approved 19 phosphate ester and water-glycol fluids and, since Underwriters' Laboratories has so far listed only one fire-resistant fluid, the Factory Mutuals' results represent the best independent information available.

According to a loss analysis made for this survey by G. C. Koth, chief special hazards engineer in the association's Standards-Laboratories Dept., the number of claims, in relation to the amount of insurance in force, has definitely decreased since the less hazardous fluids have been in use. Several factors, however, make it impossible to provide firm statistics. Also, Koth could quote no statistics to indicate a general decrease in the size of average insurance claims. But he revealed that no single incident involving a less hazardous fluid has created a loss exceeding four figures; and several fires involving mineral oil have run into six figures. Over the past six years the association has had 16 times as many claims and the average loss was 10 times as great where mineral oils were used. And there has never been a loss of life in a fire reported to the association involving less hazardous fluids.

The insuring policy of the organization allows operation without automatic sprinklers if Factory Mutual approved fluid is used in a building of noncombustible construction with no combustibles in it. Under similar conditions, installations using mineral oil or water-oil emulsions require sprinkler protection.

A Systematic Charting Method for . . .

Verifying Relay Control Circuits

THE GIST: In recent years the application of logical methods, such as switching algebra, has helped speed design of multirelay control circuits. Checking techniques, however, have not enjoyed equivalent progress. So searching for flaws in a new circuit is still mostly a matter of some "hard looking" then testing a prototype. To put the "looking" phase on a more systematic basis, a charting technique has been developed that logically analyzes the information depicted on a circuit diagram. The method yields a statement of the operations performed by every relay in the system, which can be verified against the original specifications.

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The Martin Co., Baltimore Div.

The main difficulty faced by a control engineer seeking to analyze a relay control circuit is that to determine the effect of a single relay action, he must know the state of all other relays in the circuit. This is no easy task when many relays are present, since the state of the entire system changes after each event. There is, however, a systematic method for checking multirelay circuits regardless of the number of relays in them. The method provides the designer with a time sequence of relay events and eliminates most of the possibilities for error inherent in unorganized approaches to circuit verification. The technique is best described with reference to a specific circuit—in this case the firing sequencer for the first stage of a Vanguard rocket.

The Vanguard vehicle uses a GE engine that develops 28,000 lb of thrust in its first stage. The function of the firing sequencer is to make sure that the engine's combustion process takes place in an orderly fashion. The circuit, which is shown schematically in Figure 1 (next page), contains 24 relays, five miniature limit switches, and three fuse contacts. The sequencer consists of two parts: one is located on the ground and the second is airborne. The ground sequencer initiates a function in the rocket engine; and when this function is completed properly, the airborne sequencer dispatches a feedback signal which illuminates a light for ground crew observation and triggers the ground sequencer to start the next function. If a malfunction occurs, a cutoff relay shuts down the engine.

With reference to the figure, energizing the fuel-main-valve-open solenoid allows fuel to flow into the combustion chamber. As it opens, this valve mechanically actuates two fuel main valve limit switches. A similar sequence is followed by the H_2O_2 main valve open solenoid and the H_2O_2 main valve limit switches to regulate the flow of hydrogen peroxide to the roll jets for roll control.

To open the LOX main valve to permit liquid oxygen to enter the combustion chamber, both LOX main valve No. 1 solenoid and LOX main valve No. 2 solenoid must be energized. Energizing the No. 1 solenoid releases the force holding the LOX main valve closed. Energizing the No. 2 solenoid actually opens the LOX main valve. As it opens, the valve trips the LOX main valve limit switch.

Combustion is started by means of the igniter, which incandesces and touches off the primer fuel, which is ethane. At the same time, the igniter melts the ignition indicator fuse contact. When fuel and liquid oxygen enter the combustion area, chamber pressure builds up rapidly. At a predetermined pressure the burp board blows out, breaking the combustion indicator fuse contact.

The first step in the analysis is to prepare a list showing each circuit element and what must occur to cause it to operate. This list, for example, indicates the conditions under which a particular relay is energized or a fuse contact is broken. The following is a sample of a portion of the table as it would be written for the circuit of the figure.

Conditions for Relay Energization

ACI ~ 28 vdc • Comb Ind
AFVO ~ 28 vdc • Fuel MV Open

$$AII \sim 28\text{ vdc} \cdot \overline{ALVC \cdot \text{Ign Ind}}$$
$$APVC \sim 28\text{ vdc} \cdot \overline{H_2O_2\text{ MV Open Sol}}$$
$$APVO \sim 28\text{ vdc} \cdot H_2O_2\text{ MV Open Sol}$$
$$CD \sim 28\text{ vdc} \cdot GS$$
$$CI \sim 28\text{ vdc} \cdot GS \cdot (CI \vee \overline{I}) \cdot ACI$$

The key to the symbolism used in the table is as follows:

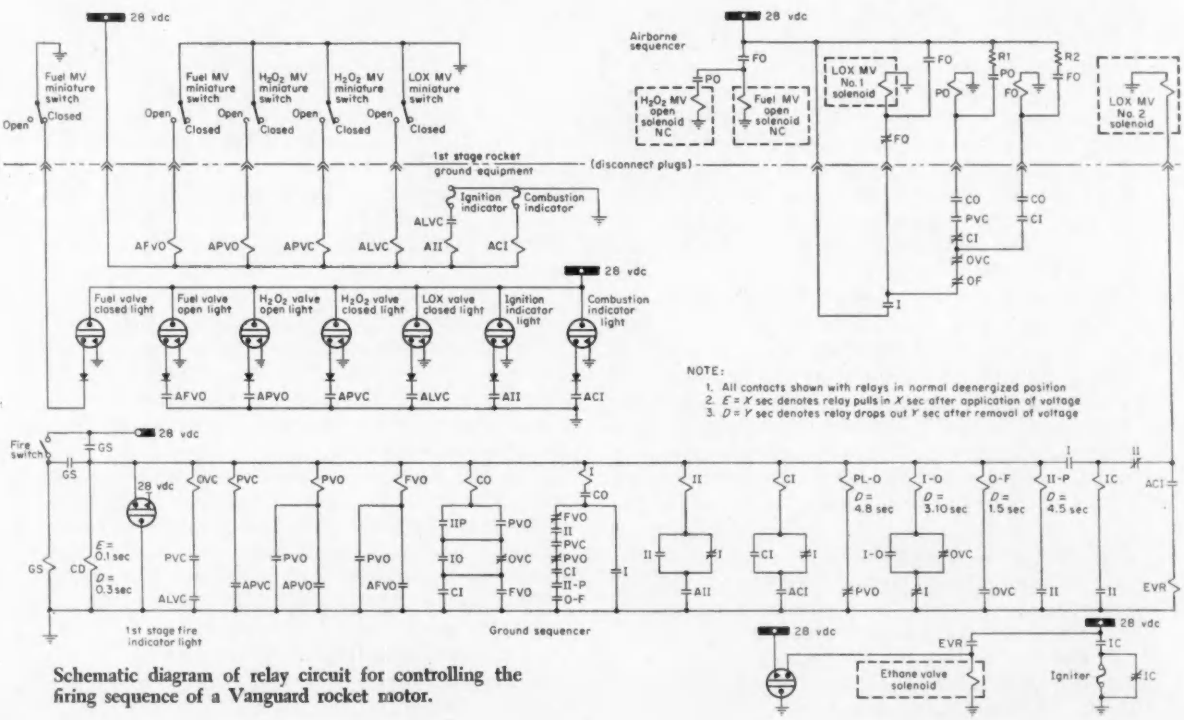
$ALVC$ = relay $ALVC$ energized
$\overline{ALVC}$ = relay $ALVC$ deenergized
Ign Ind = ignition indicator fuse contact intact
$\overline{\text{Ign Ind}}$ = ignition indicator fuse contact broken
Fire Switch = switch is closed
$\overline{\text{Fire Switch}}$ = switch is open
$\sim$ = ... is . . . . if . . . .
$\cdot$ = and
$\vee$ = or

For example, $CI \sim 28\text{ vdc} \cdot GS \cdot (CI \vee \overline{I}) \cdot ACI$ is read: relay *CI* is energized if the 28-vdc supply is turned on and relay GS is energized and (relay *CI* is energized or relay *I* is deenergized) and if relay *ACI* is energized. The appearance of CI on both sides of the $\sim$ symbol merely means it can latch itself in. Again, $APVC \sim 28\text{ vdc} \cdot \overline{H_2O_2\text{ MV Open Sol}}$ is read: relay *APVC* is energized if the 28-vdc supply is turned on and the H_2O_2 main valve open solenoid is deenergized. By deenergizing the H_2O_2 main valve open solenoid, the H_2O_2 main valve closes, closing the H_2O_2 main valve limit switch contacts and energizing relay *APVC*. The statement $\overline{\text{Ign Ind}} \sim \overline{\text{Igniter}}$ is read: the ignition indicator fuse contact breaks if the igniter fuse contact breaks. The igniter receives current during the sequencing action. This, in turn, melts the ignition indicator fuse.

The list is prepared in alphabetical order. The information for preparing the list is obtained directly from the schematic drawing. The second step in the analysis is to prepare a list as shown in Table I. This is prepared from the aforementioned list and contains essentially the same information but in different form. With a little practice, Table I can be prepared directly from the schematic drawing without the need for making a detailed listing first.

The relays are tabulated alphabetically in the left-hand column. The conditions for energizing a particular relay are written in the horizontal row assigned to it. For example, the *CI* row contains the numbers 1, 2, 3, $\overline{3}$, 4. This means that to energize relay *CI*, the conditions numbered 1 through 4 must be fulfilled as a combination of either 1, 2, 3, 4 or 1, 2, $\overline{3}$, 4. In equation form these conditions may be stated as $CI \sim 1 \cdot 2 \cdot (3 \vee \overline{3}) \cdot 4 = CI \sim 28\text{ vdc} \cdot GS \cdot (CI \vee \overline{I}) \cdot ACI$. A number means that the relay appearing in the column above it must be energized; a number with a bar above it means the relay appearing in the column above it must be deenergized.

As another example, consider relay *I*. The row in Table I pertaining to this relay contains the



Schematic diagram of relay circuit for controlling the firing sequence of a Vanguard rocket motor.

TABLE I—CONDITIONS FOR RELAY PULLIN

	ACI	AFVO	AII	ALVC	APVC	APVO	CD	CI	CO	Combustion indicator	Ethane valve solenoid	EVR	Fire switch	FO	Fuel main valve open solenoid	FVO	GS	H_2O_2 main valve open solenoid	Igniter	Ignition indicator	I	IC	II	II-P	I-O	LOX main valve No. 1 solenoid	LOX main valve No. 2 solenoid	OVC	OF	P-LO	PO	PVC	PVO	28-vdc supply
ACI										2																								1
AFVO															2																			1
AII				2																3														1
ALVC																										2	$\overline{2}$							1
APVC																		$\overline{2}$																1
APVO																		2																1
CD																	2																	1
CI	4							3									2				$\overline{3}$													1
CO								5								5	2							3	4			$\overline{4}$					3	1
$\overline{\text{Combustion}}$ indicator																																		
Ethane valve solenoid												2																						1
EVR	5																2				3		$\overline{4}$											1
Fire switch													1																					
FO								5	6					2-6							2							$\overline{4}$	$\overline{3}$					1
Fuel main valve open solenoid														2																				1
FVO		3															2																3	1
GS													2				2																	1
H_2O_2 main valve open solenoid														2																	3			1
$\overline{\text{Igniter}}$																						2												1
$\overline{\text{Ignition}}$ indicator																			$\overline{1}$															
I								8	3							$\overline{4}$	2				4-10		5	9					10			6	$\overline{7}$	1
IC																	2				3		4											1
II			4														2				$\overline{3}$		3											1
II-P																	2						3											1
I-O																	2				$\overline{4}$				3			$\overline{3}$						1
LOX main valve No. 1 solenoid								$\overline{5}$	7					$\overline{2}$ 2-8							3-8							$\overline{4}$	$\overline{3}$		8	6		1
LOX main valve No. 2 solenoid																	2				3		$\overline{4}$											1
OVC				4													2															3		1
OF																	2											3						1
P-LO																	2																$\overline{3}$	1
PO								$\overline{5}$	7												2							$\overline{4}$	$\overline{3}$	2-7		6		1
PVC					3												2																	1
PVO						3											2																3	1
28-vdc supply																																		1

numbers 1 to 10. There are two ways to fulfill conditions 1 to 10. One method is: 1, 2, 3, $\bar{4}$, 5, 6, $\bar{7}$, 8, 9, 10. Observing the relays in the column above each number, this condition reads: $I \sim 28$ vdc $\cdot\ GS \cdot CO \cdot \overline{FVO} \cdot II \cdot PVC \cdot \overline{PVO} \cdot CI \cdot II\text{-}P \cdot OF$. Another method is: 1, 2, 3, 4-10. This condition reads: $I \sim 28$ vdc $\cdot\ GS \cdot CO \cdot I$. Here relay *I* has "latched" itself in and thus, singly, has the same effect on the circuit as have conditions 4 through 10 in combination.

The third step gives the desired result, a time sequence of events. This is determined with the aid of Table I only. The schematic need no longer be consulted; no memory is required. In the time sequence chart, Table II, the components are tabulated alphabetically in the left-hand column in their initial conditions. These initial conditions depend, of course, upon the point in the cycle at which the analysis is begun. Here all relays are deenergized, fuse contacts are intact, and valve solenoids are deenergized.

The remaining vertical columns are in this case numbered 1 to 31, each column corresponding to an event in the cycle of operations. The energization or deenergization of a relay is called an occurrence; each occurrence is a consequence of a previous event. The first event written in column 1 is generally a manual operation, and in this application, it is the turning on of the 28-vdc supply. By referring to the column in Table I headed 28-vdc Supply, the possible succeeding occurrences are determined. For this example the initial event sets up every other occurrence except $\overline{\text{Comb}}$ Ind, fire switch, and $\overline{\text{Ign Ind}}$.

Each possible occurrence is taken up, one at a time. Beginning with *ACI* in the tabulation on the left of Table I, it is noted that *ACI* is energized as soon as the 28-vdc supply is switched on, if the combustion indicator fuse is intact. The columns to the left of event 2 or column 2 are now examined to show that the combustion indicator fuse is indeed intact. Therefore, *ACI* becomes energized and this fact is recorded in column 2. Next, consider relay *AFVO* in Table I. Relay *AFVO* is energized after the 28-vdc supply is activated if the fuel main valve open solenoid is energized. But Table II indicates that the fuel main valve open solenoid is actually deenergized. Therefore, relay *AFVO* remains in its original state and the next possibility is considered.

Continuing in this fashion, it is found that relays *ACI*, *ALVC*, and *APVC* become energized. These constitute the second event and are recorded in column 2 of Table II.

The consequences of each occurrence in event 2 are now considered. For example, by examining the column in Table I headed *ALVC*, the possible succeeding occurrences are seen to be *AII* and *II*.

To investigate these relays one at a time, first study the row marked *AII* in Table I, which specifies that $AII \sim 1 \cdot 2 \cdot 3 = 28$ vdc $\cdot$ ALVC $\cdot$ Ign Ind. From the columns to the left of event 3, which is presently under consideration, it is apparent that these conditions have been fulfilled and relay *AII* becomes energized. This is noted in column 3.

Table I also reveals the conditions for energizing relay *II*. From Table II, however, it is evident these conditions are not fulfilled (e.g., relay *GS* must be energized but it is not); therefore, relay *II* remains deenergized. No entry is made in column 3 at this time, because only changes in state are recorded. After similarly investigating the other possible results of event 2 (energization of relays *ACI* and *APVC*), it is found that energizing *AII* is the only consequence and constitutes the entire event 3.

Proceeding in like manner, all events are determined. The scheme of the present analysis should now be clear. Table II holds the memory. The state of the system prior to any particular event (point in time) is duly recorded in the columns before that event. The possible consequences of the events immediately preceding the one being considered are listed in Table I. Here are found the conditions necessary for each possible occurrence. Whether these conditions do, in fact, exist is found from Table II. If agreement exists, this possible consequence occurs; otherwise it does not.

Sequencing action

The completed Table II presents a full picture of the sequence of operations followed by the circuit of the figure. Action is initiated by turning on the 28-vdc supply, after which relays *ACI* through *AII* are energized. At this point, the action stops. Then the fire switch is thrown and the sequence of control resumes. After relays *GS* through *FVO* are energized, electrical sequencing stops again. However, combustion is taking place in the fire chamber. When the pressure is high enough, the burp board is blown out and the combustion indicator contact is broken. The sequence of energization then proceeds to relay $\overline{PLO}$, after which liftoff occurs.

If a malfunction occurs during the combustion process cutoff relay *CO* becomes deenergized and shuts down the rocket engine. The state of relay *CO* during the sequencing action is shown at the bottom of Table II. It is energized when the fire switch is thrown and must stay energized throughout the sequencing. Time delay relays allow a prescribed amount of time for each part of the combustion process.

After a little practice, the control engineer should find this charting technique invaluable in verifying the cycle of operation of a new relay circuit. Beginning with the schematic diagram, he progresses systematically to a full description of each event in the cycle. A comparison of this charted description against the original requirement indicates positively whether or not the circuit design has been set up to function correctly.

TABLE II–SEQUENCE OF EVENTS

	Turn on 28-vdc supply			Fire signal																			Combustion								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
$\overline{\text{ACI}}$ / $\overline{\text{AFVO}}$		ACI																			AFVO				$\boxed{\text{ACI}}$						
$\overline{\text{AII}}$ / $\overline{\text{ALVC}}$		ALVC	AII										$\boxed{\text{AII}}$			$\boxed{\text{ALVC}}$															
$\overline{\text{APVC}}$ / $\overline{\text{APVO}}$		APVC																											$\boxed{\text{APVC}}$ APVO		
$\overline{\text{CD}}$ / $\overline{\text{CI}}$					CD	CI																				$\boxed{\text{CI}}$					
$\overline{\text{CO}}$								CO																							
Combustion indicator																								$\boxed{\text{Comb ind}}$							
$\overline{\text{Ethane valve solenoid}}$																Eth val sol											$\boxed{\text{Eth val sol}}$				
$\overline{\text{EVR}}$															EVR											$\boxed{\text{EVR}}$					
$\overline{\text{Fire switch}}$				Fire switch																											
$\overline{\text{FO}}$																			FO												
$\overline{\text{Fuel main valve solenoid}}$																				Fuel MV solenoid			Combustion chamber pressure builds up								
$\overline{\text{FVO}}$ / $\overline{\text{GS}}$					GS																	FVO									
$\overline{H_2O_2 \text{ main valve open solenoid}}$																												H_2O_2 MV open solenoid			
Igniter											$\boxed{\text{Ign}}$																				
Ignition indicator												$\boxed{\text{Ign ind}}$																			
$\overline{\text{I}}$ / $\overline{\text{IC}}$									I	IC					$\boxed{\text{IC}}$																
$\overline{\text{II}}$ / $\overline{\text{II-P}}$						II	II-P							$\boxed{\text{II}}$	$\boxed{\text{II-P}}$ → 4.5 sec																
$\overline{\text{I-O}}$						I-O				$\boxed{\text{IO}}$ → 3.1 sec																					
$\overline{\text{LOX}}$ main valve No. 1 solenoid										LOX MV No.1 sol																					
$\overline{\text{LOX}}$ main valve No. 2 solenoid															LOX MV No.2 sol																
$\overline{\text{OVC}}$ / $\overline{\text{OF}}$							OVC	OF									$\boxed{\text{OVC}}$	$\boxed{\text{OF}}$ → 1.5 sec													
$\overline{\text{P-LO}}$ / $\overline{\text{PO}}$						P-LO																					PO				$\boxed{\text{PL-O}}$ → 4.8 sec
$\overline{\text{PVC}}$ / $\overline{\text{PVO}}$						PVC																								$\boxed{\text{PVC}}$ PVO	
$\overline{\text{28-vdc supply}}$	28-vdc supply																														

CO	1–5	6	7	8–9	10	11–14	15	16	17	18–21	22	23–25	26	27–29	30
CI / FVO		CI									FVO		$\boxed{\text{CI}}$		
I-O / $\boxed{\text{OVC}}$		I-O	OVC		$\boxed{\text{I-O}}$ → 3.1 sec				$\boxed{\text{OVC}}$						
II-P / PVO			II-P				$\boxed{\text{II-P}}$ → 4.5 sec								PVO

New Ultra-High-Speed Ferrite Core For Simplified Memory Plane Construction

Now RCA Offers TWO Memory Cores for Impulse Switching to 0.2 Microsecond

New RCA memory core XF4930 joins the RCA 400M1 in adding new flexibility to memory system design. Specifically developed for operation under impulse switching conditions in magnetic memory systems, XF4930 switches in 0.25 microsecond and provides excellent discrimination at relatively low driving currents.

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Nominal Operating Characteristics At 25°C	Type XF4930	Type 400M1	Units
Read Driving Current (I_R)	570	380	ma
Full Write Current (I_{FW})	255	280	ma
Impulse Write Current (I_{IW})	130	180	ma
Digit Write Current (I_{DW})	125	100	ma
Read Pulse Rise Time (t_r)	0.1	0.1	μsec
Full and Impulse Write Current Rise Time (t_r)	0.1	0.08	μsec
Digit Write Pulse Rise Time	0.1	0.15	μsec
Switching Time (t_s)	0.25	0.2	μsec
Response: "Undisturbed Read-1" (uV_{R1})	100	50	mv
"Disturbed 0" (dV_Z)	15	8	mv
Size	.050x.030x.015	.030x.018x.010	inch

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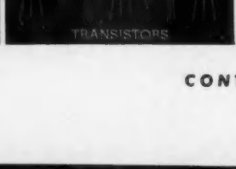

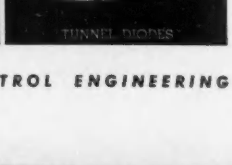

What's Available for Digital Data Transmission

Here's a quick look at some of the principal problems of data transmission that affect transmission equipment, followed by a survey of the available equipment for use with leased wire lines and toll exchange networks. Two tables classify the equipment of 13 manufacturers according to modulation technique, recording medium, error check technique, and data rate. This survey discusses equipment for use with telegraph and voice-grade lines only.

ROBERT F. SHAW, Digitronics Corp.

Digital data transmission over communication circuits is as old as telegraphy, but has undergone a tremendously accelerated development recently. This continuing growth is so rapid that an official of American Telephone and Telegraph Co. recently predicted that eventually the volume of data communication over the telephone networks will equal voice communication.

Figure 1 shows the principal elements of a data communication system: solid lines indicate data flow and dotted lines indicate control functions. Reading or recording of data is done as in other data processing systems—by paper tape or punched card readers and punches, magnetic tape transports, and various types of printing devices. The memory shown is necessary only if the recording medium operates at a data rate appreciably different from that of the communication circuit or if a change of coding format is necessary. The memory may also be useful if there are transmission errors, holding each message for retransmission if an error is detected.

Unlike the reader or recorder and the memory, the other two elements of the system—terminal devices and data couplers—are peculiar to data transmission. It is convenient to consider the terminal devices separately from the data couplers because there is increasing tendency for the communication companies to supply the terminal devices (to assure compatibility with communication circuits and to guarantee minimum error rates by limiting data rates). Many manufacturers provide data couplers to work with these terminal devices.

Communication circuits classified by speed

Data circuits are classified in terms of the rate at which data may be transmitted. Until recently all data transmission was done on telegraph-grade circuits at rates of about 80 bits per sec or less. Paper tape equipment has long been used by the Bell System companies and Western Union, and data communication using such equipment is still prevalent.

The first approach to faster data transmission involved the multiplexing of several telegraph channels on one voice channel, which has several times the bandwidth of a telegraph channel. While satisfactory in many applications, breaking up a group of data into several tapes for simultaneous transmission is not always convenient. A number of

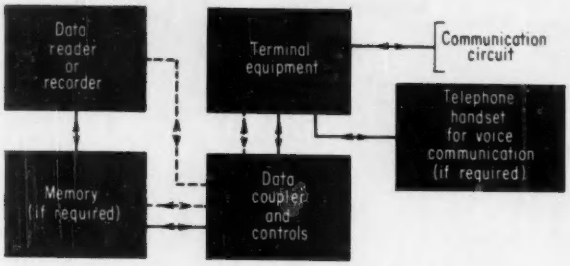

FIG. 1. Basic elements of one station in a data communications system.

manufacturers have therefore developed terminal equipment designed to provide a single high-speed channel (1,200 or more bits per sec) on a voice line. Concurrently, Bell Telephone Laboratories undertook development of its own terminal equipment.

When the volume of data to be handled is large several voice channels can be used simultaneously, although this is subject to the same drawbacks as the multiplexing of telegraph channels unless the multiple channels are used for simultaneous transmission of the different bits of a single character.

If the facilities are available, faster transmission is possible using either wide band (carrier grade) lines or microwave links. Such facilities have not yet been widely used for commercial data transmission, however. Telephone (voice-grade) circuits are now receiving the most attention because of their wide availability and their ability to provide much greater data handling capacity than telegraph circuits. Much of this discussion will be devoted to equipment designed for telephone circuits.

Check techniques raise reliability

Error checking has always received serious attention in the design of data processing equipment, but it is even more important in the design of data communications equipment. Noise of both the drop-out and pick-up variety occurs, and the circuits introducing the noise are not under the control of the transmission equipment designer. Many error detection and correction techniques are used in available equipment, including various parity schemes and automatic retransmission methods. Also, most data transmission equipment is designed to operate

Data Communication Equipment for Use on Toll Telephone Circuits

(subject in each case to approval of the common carrier, if any)

TABLE I

Manufacturer and Model	Equipment Type: Tone generators and detectors	Carrier terminals	Voice line transceivers	Telegraph terminals	Complete systems	Data Rate (bits per sec)	Remarks
Bendix-Pacific Electro-span	•				•	2,400	Using wide-band facilities
Daystrom					•		Technical details not available
Friden Dual Teledata					•		14.2 characters per sec on two channels simultaneously
IBM 65 & 66 Card transceiver					•		3 to 5 cards per min on telegraph channels (67 terminal), 10 to 11 on telephone channel (68 terminal). 4 units may be multiplexed on telephone channel
Lenkurt Datatel		•					
Lenkurt Quaternary			•			2,400	Up to 3,360 bits per sec on selected voice channels
Lynch B-109		•					
Moore Monitron	•				•	1,000	Data rate applies to Monitron coder and decoder
RCA 130					•	600	Checking by bit-parity coding and carrier presence check
Rixon Sebit-24			•			2,400	
Stromberg-Carlson SC301			•		•	2,400	
Systematics				•		80	Couples IBM 24 or 26 card punch to teleprinter circuits

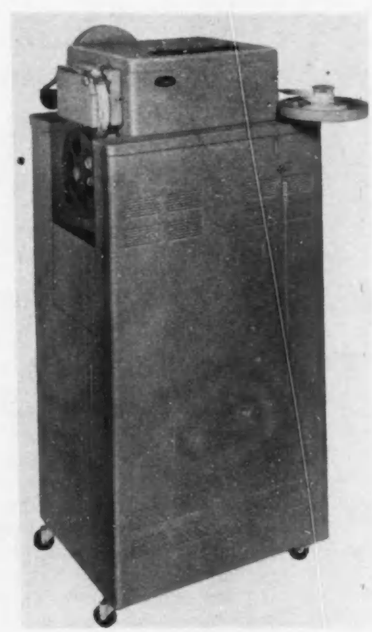

FIG. 2. Friden Dual Teledata terminal. (Photo courtesy Friden, Inc.)

unattended in response to remote signals, and many include some means of checking for noisy conditions on the transmission circuit.

TYPICAL EQUIPMENT FOR DIGITAL DATA TRANSMISSION

"Terminal equipment" is equipment which transforms dc-level data signals into signals suitable for transmission over communication circuits. "Mark" and "space" are communication terms for "one" and "zero" (or "pulse" and "no pulse"), respectively. Most communication circuits presently employ the two-level "mark-space" system. A three-level system is also possible in which one level represents the absence of data and the other two are used for mark and space.

Telegraph circuits (at least the subscriber loop connecting the subscriber with the nearest central office) are capable of transmitting dc, and in general require no terminal equipment more elaborate than a relay. But these circuits can reliably transmit data at a rate no greater than about 10 characters per sec, so an increasing amount of data transmission now is taking place over voice-grade facilities. Here an entirely different situation exists.

Voice-grade or telephone circuits can transmit frequencies up to about 3,000 cps, but are limited at the low end to a minimum of about 250 cps. Thus the dc levels representing data cannot be applied directly to the line. Instead, the mark and space signals must be converted to frequencies within the line's rating. An obvious way to do this would be to send an audio frequency of, say, 2,000 cps as the mark signal but transmit nothing for the space signal. Such an arrangement is generally unsatisfactory because line noise during the space time can give rise to spurious signals. Furthermore, echo suppressors and compandors on the circuit will not operate satisfactorily unless the signal is reasonably continuous. The usual solution is to use "frequency shift keying" (FSK), in which the space signal is sent on one frequency (often referred to as the carrier) and the mark signal is sent on a different frequency. Thus the function of the terminal equipment for a voice-grade line is to convert mark-space data signals to FSK signals (with frequen-

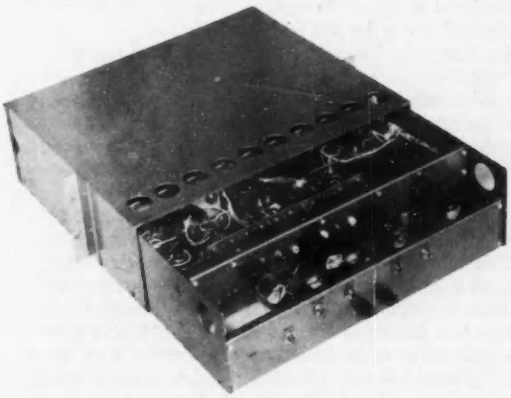

FIG. 3. Transmitter of the Lynch B-109 carrier data transmission system. (Photo courtesy Lynch Communication Systems, Inc.)

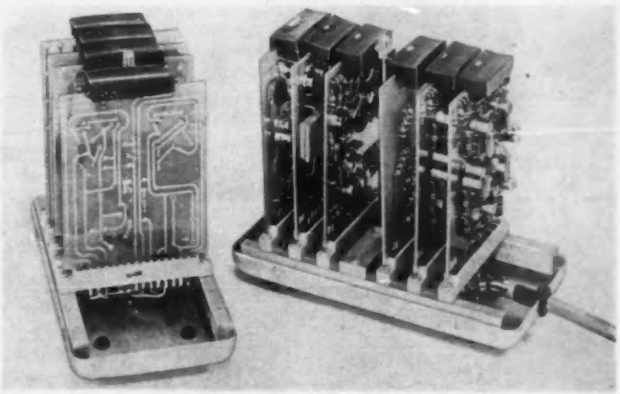

FIG. 4. Moore Associates "Monitron" coder and decoder. (Photo courtesy Moore Associates).

FIG. 5. Stromberg-Carlson's high speed binary data transceiver, Model SC301, transmits and receives binary data over commercial telephone lines at 2,400 bits per second. (Photo courtesy Stromberg-Carlson)

FIG. 6. Magnetic tape terminal developed by Stromberg-Carlson, using the Model SC301 data transceiver. (Photo courtesy Stromberg-Carlson)

cies, voltage levels, and source impedance appropriate to the line requirements) and at the receiving end convert such signals back to dc mark-space signals. The terminal equipment may also include equalizers, filters, and carrier detectors.

Where wide-band facilities are available the terminal equipment is similar to that used on voice-grade facilities, with the exception that many space (or carrier) frequencies may be used within the range of the circuit. This technique is standard practice in the telephone industry for both voice and telegraph circuits, since it permits simultaneous independent transmission of a number of messages over a single circuit—wire line, coaxial cable, or microwave link. Where FSK is used on carrier circuits the carrier may have any frequency within the pass band of the circuit, but the "mark" frequency for each carrier should differ from its carrier frequency by only a small amount.

Carrier data terminal equipment is provided by several manufacturers but, with the exception of a few public utilities, railroads, and similar users who have their own privately-maintained communication circuits, the chief market for carrier equipment is among telephone and telegraph companies.

Terminal equipment and systems for use on leased lines

A variety of terminal equipment is available for use on leased or private lines, ranging from subassemblies to complete systems incorporating all the elements shown in Figure 1. Table I summarizes some of the available equipment. When used on lines leased from common carriers, equipment must be compatible with such facilities. (The addresses of all manufacturers mentioned in this article are listed in Table II.)

TABLE II—MANUFACTURERS OF DIGITAL DATA COMMUNICATION EQUIPMENT

Bendix-Pacific Div., Bendix Aviation Corp.
11600 Sherman Way, North Hollywood, Calif.
Daystrom, Inc.
4455 Miramar Rd., La Jolla, Calif.
Digitronics Corp.
Albertson Avenue, Albertson, L. I., N. Y.
Friden, Inc.
San Leandro, Calif.
International Business Machines Corp.
Data Processing Division
112 East Post Rd., White Plains, N. Y.
Lenkurt Div., General Telephone & Electronics
San Carlos, Calif.
Lynch Communication Systems, Inc.
695 Bryant St., San Francisco 7, Calif.
Moore Associates, Inc.
2600 Spring St., Redwood City, Calif.
Radio Corp. of America
Electronic Data Processing Division
Camden 2, N. J. (for DaSpan system)
Radio Corp. of America
Industrial Computer Systems Dept.
21 Strathmore Road, Natick, Mass., (for RCA 130 system)
Rixon Electronics, Inc.
2414 Reedie Drive, Silver Spring, Md.
Stromberg-Carlson Div., General Dynamics Corp.
1400 N. Goodman St., Rochester 3, N. Y.
Systematics Div., General Instrument Corporation
3216 West El Segundo Blvd., Hawthorne, Calif.

Bendix Pacific Div. of Bendix Aviation Corp., in addition to a high-speed (2,400 character per sec) system developed for the Army Signal Corps, has developed an industrial data communication system called Electro-Span. System details were not available at the time of writing. The tone generators and tone detectors used are also available separately.

Daystrom, Inc. has developed a data transmission system for transmission of process data. This system features the use of a large scale tape programmed sampling system for analog data. The same company has developed a second system for interchanging computer maintenance data between a field computer installation and the manufacturer's factory service personnel (Control Engineering, October 1960, page 27).

Friden, Inc.'s Dual Teledata paper tape transmission system (Figure 2) transmits 14.2 alphanumeric characters per sec by using two 100 word per min telegraph-grade lines and transmitting characters alternately over the two lines. Interlaced parity checking is used and transmission is halted for manual intervention if an error is detected.

The first widely-used data transmission system intended primarily for commercial use was the IBM card transceiver, introduced in 1954. This device has now been adapted for use on toll lines, and its characteristics are described later.

Lenkurt, a subsidiary of General Telephone and Electronics, and a long-established supplier of carrier terminal equipment, provides a carrier terminal for the simultaneous transmission of 18 to 26 telegraph channels (using FSK) on a 4-wire channel in its Type 32A Datatel System. They also manufacture a Quaternary Data Transmission System—a terminal subset which accepts or produces serial digital data and provides coupling to a voice-quality line. The system handles the serial data two bits at a time, converting each of the four possible bit combinations (00, 01, 10, 11) into a different tone frequency; in this way data rates of 2,400 bits per sec are achieved on standard voice circuits, and up to 3,360 bits per sec on selected "clean" voice channels carefully equalized for phase delay.

Lynch Communication Systems, Inc. manufactures a voice-frequency carrier transmitter and receiver (Figure 3) through which up to 9 voice-grade channels can be transmitted over one carrier circuit. By transmitting the carrier modulating frequency as well as one of the sidebands, this equipment makes synchronous data transmission possible. This is not practical with many standard carrier circuits which usually use a suppressed-carrier single-sideband technique that destroys the precise phase relation between transmitter and receiver needed for synchronous transmission.

Moore Associates, like Bendix Pacific, supplies both complete data communication systems (primarily for supervisory and control purposes for utilities and the petroleum industry) and tone generators and receivers for FSK communication. The Monitron coder and decoder (Figure 4) are designed for parallel to serial and serial to parallel conversion, fulfilling the function of the data coupler element used in serial binary communication.

Radio Corp. of America manufactures the Model

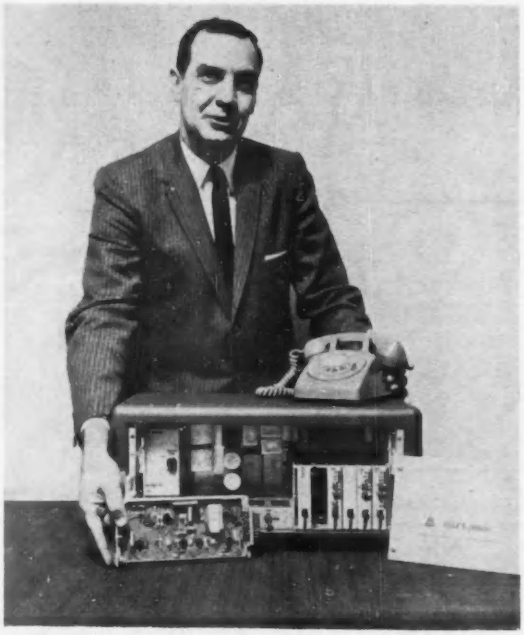

FIG. 7. Bell System Model 200 Data-phone subset shown by Harvey J. McMains, AT&T administrator of Data-phone service. (Photo courtesy AT&T)

130 Industrial Data Transmission Link as a part of their industrial control system. The 130 is a complete digital data transmitting and receiving station designed to transmit at the rate of 10, 100, or 600 bits per sec depending on the type of communication circuit used. The construction is modular for flexibility in "on-line" applications. Error checking is done with a "bit-parity" code plus a carrier-presence check on the circuit.

Rixon Electronics, Inc., with their Sebit 24 Data Transceiver, can transmit as much as 2,400 bits per sec on a voice circuit with 3,000 cps nominal bandwidth. A high data rate is achieved through a unique afc system and synchronous detection of data. Monitoring is facilitated by a built-in oscilloscope and status-indicating circuits. The transceiver accepts and supplies completely serial data.

Stromberg-Carlson Div. of General Dynamics Corp. manufactures a 2,400 bit per sec binary data transceiver, Model SC301 (Figure 5), which uses vestigial sideband transmission (carrier and one sideband) with an afc system for synchronous detection of data. The SC301 accepts and supplies data in serial binary form. The company has also used the transceiver as the basis for a complete data transmission system now being used by Convair for transmitting data from one plant to its computer facility, where the data are recorded directly on magnetic tape (Figure 6).

The Bell System Data-phone subset

Communications companies have always been reluctant to permit connection to their circuits of any equipment except their own. Where customer-supplied equipment is permitted, it is restricted to leased lines, and even then the equipment must be compatible with the carrier's facilities.

Until recently all data communication, except some teleprinter communication, was sent over either privately owned channels or circuits leased from common carriers such as American Telephone and Telegraph Co. and its affiliated companies or Western Union Telegraph Co. The high cost of leased circuits and the relatively low data rates of available equipment made any extensive use of such equipment uneconomical, particularly where distances involved were large.

Bell Telephone Laboratories has been developing a series of "digital subsets" designed to connect equipment for transmitting digital data directly to voice circuits on the regular telephone exchange network. Using this equipment, of which the Bell System Data-phone 200 is typical, a 25 to 1 increase in data rate is possible compared to that obtainable with standard (60 wpm) telegraph-grade circuits and, more significantly, transmission can be on an individual call bands. The user is charged at standard toll rates only for the time the circuit is used.

This development is significant economically. The new facilities can transmit as much data in one 20-min toll call between New York and San Francisco, costing $12.45, as can be carried in 8 hours on a 60 wpm leased teleprinter circuit, at $75.60 (based on a monthly rate of $1,663.00 and assuming use of the line 22 days per month).

There are three models of Data-Phone digital subsets now in use. Model 100 transmits and receives data serially at 75 bits per sec and is the most widely used, with 600 to 700 in use in October 1960. This model permits the use of Model 28 Teletypewriters on voice circuits and is also used in connection with the Friden Teledata and RCA DaSpan paper tape data transmission systems. Model 400 is a small, compact unit which handles 20 characters per sec, and is used with the IBM Model 1001 Card Transmitter described later. In the model 400 each character is represented by two simultaneous tones, with 16 tone combinations available.

For large-scale data transmission, the Data-phone 200 (Figure 7) is the most interesting. It handles serial binary data at 1,200 bits per sec, and forms the basis of Digitronics Corp.'s Dial-o-verter system, IBM's 1009, 7701, and modified card transceiver systems, as well as the Teletype 1,000 wpm punch and reader.

The Model 200 Data-phone accepts and supplies serial binary data at any rate up to 1,200 bits per sec. It is normally supplied with a standard telephone set which provides regular voice communication as well as data transmission, thus letting the sending and receiving operators make any necessary arrangements before transmitting data. The Model 200 can also be used for unattended operation at either end, the calling station initiating either transmission or reception at the called station.

Systems for use on toll exchange networks

All of the systems described below are designed for use with one of the three models of Data-phone subsets just described, and thus do not include terminal equipment. While these systems will probably be most used on a toll basis, they are in most cases adaptable with minor modifications to use with terminal equipment other than Data-phone

Data Communication Equipment for Use on Leased or Private Lines

TABLE III

Manufacturer and Model	Medium and speed (characters per sec or cards per min)					Checking			Unattended Operation		Remarks
	Data-phone Subset Model	Paper Tape *	Punched Cards *	Magnetic Tape *	Other *	Code	Other checks	Automatic retransmission	Receive	Transmit	
Digitronics Dial-o-verter	200	100	80	150	150	7 bit T & L parity	Line condition	•	•	•	Communication between different media or with line printer possible
Friden Teledata	100	7 to 10				Various (see note)					5, 6, 7 or 8 level code; checking, if any, depends on code used
IBM 65-66 transceiver	200		9 to 10			4 out of 8					
IBM 1001	400		see note		see note	2 out of 8	Message length		•		20 numeric characters per sec from card or keyboard
IBM 1009	200				150	7 bit T & L parity		•			Used with 1401 computer; punched cards or magnetic tape via computer memory
IBM 7701	200			150		7 bit T & L parity		•			Communication with IBM 1009 possible
RCA DaSpan	100	7.1				Inter-laced parity					

* Speeds shown are recording rates; where terminals use different media, speed of recording device determines transmission rate.

FIG. 8. Dial-o-verter paper tape terminals. Transmitting terminal on left desk, showing paper tape strip reader; receiving terminal with high speed punch on right desk. Each telephone handset rests on its Data-phone subset. Magnetic tape terminal is also available. (Photo courtesy Digitronics Corp.)

where the volume of data justifies private line operation. The Data-phone subset is usable on leased lines of Bell System affiliates. Table III summarizes some of the available equipment.

The equipment described below constitutes the "data coupler" of the system in Figure 1 (plus the memory where that element is required). The data coupler has three functions: 1) to provide required conversion at the transmitting end (tape, card, or keyboard format to terminal equipment) and the opposite conversion at the receiving end; 2) to respond to and provide any control signals used by the terminal equipment and the data reading or recording equipment; and 3) to perform error checks and take action when errors are discovered.

Digitronics Corp. manufactures the Dial-o-verter System. Using the company's Model 599SR Dial-o-verter Coupler and the Model 200 Data-phone, the system provides communication via punched paper tape, punched cards, or magnetic tape. Figure 8 shows the paper tape terminal. Data rates vary from 100 to 150 characters per sec, depending on the type of data storage medium used: if a paper tape punch is used at the receiving end, the rate is 100 characters per sec, while if magnetic tape is used, the rate is 150 characters per sec (the limitation in the latter is the Data-phone terminal).

Extensive error-checking facilities are provided in all models, using both transverse and longitudinal parity, and automatic retransmission in case of error is possible where the input medium permits or where a memory is used. A printing counter records the number of any message in which an error is detected and the total number transmitted.

The system uses a common data format on the communication circuit regardless of the data storage medium, permitting data originating from paper tape, cards, or magnetic tape to be received and recorded on any of these mediums. Special editing and format control features are optional.

Friden's Teledata system (Figure 9) was one of the first data communications systems, other

FIG. 9. Friden Teledata system. (Photo courtesy Friden, Inc.)

FIG. 10. IBM 7701 Magnetic Tape Terminal uses a Model 200 Data-phone subset. (Photo courtesy IBM)

FIG. 11. IBM Model 1009 data transmission unit, for use in conjunction with the IBM 1401 Computer and Model 200 Data-phone subset. (Photo courtesy IBM)

FIG. 12. Transmitting unit of IBM 1001 data transmission system. Receiving unit uses key punch for recording data. Both use Model 400 Data-phone subset. (Photo courtesy IBM)

than Teletype, to make use of toll circuits for data transmission. Punched tape is the storage medium, and 7 to 10 characters per sec are transmitted using the Model 100 Data-phone subset. Advantage is taken of any checking features of the tape code, and detection of an error halts transmission.

International Business Machines Corp. can now supply its Model 65 or 66 Card Transceiver, in use on leased lines since 1954, with modifications which permit use with the Model 200 Data-phone subset on toll lines. The system uses a 4-out-of-8 code for error checking and is designed for attended operation. Because the data rate is relatively low (9 to 10 cards per min), an error halts operation.

IBM also makes two other systems for use with the Data-phone 200 subset. These are the Model 7701 Magnetic Tape Terminal (Figure 10) and the Model 1009 Data Transmission Unit (Figure 11) for interconnecting their Model 1401 computer and the Data-phone subset. Both units transmit data in magnetic tape format, and may thus communicate with each other. Error checking is by means of the same parity checks used with magnetic tape, and automatic retransmission in case of error is possible. Both units are designed for attended use.

For data origination at multiple points, IBM also provides a very small, compact, and economical card transmitter, Model 1001 (Figure 12), which uses the Data-phone 400 subset. The unit will read up to 22 columns from a manually-inserted card and has a keyboard for manual insertion of additional data. The receiving terminal uses a Model 24 or 26 key punch and is for unattended use. A 2-out-of-8 cod permits error checking.

Radio Corp. of America, in their DaSpan system, use their Model 5901-7 T-R Unit as a coupler between a paper tape reader or punch (included in the 5901-7 unit) and a Model 100 Data-phone subset. The system operates at 7.1 characters per sec and uses both a regular parity and an interlaced parity check. Detection of an error halts operation and manual intervention is required.

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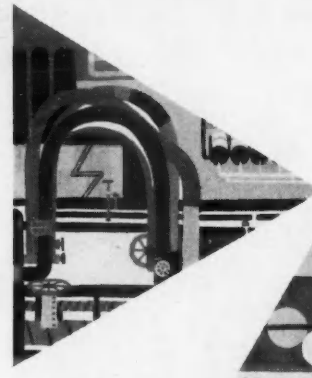
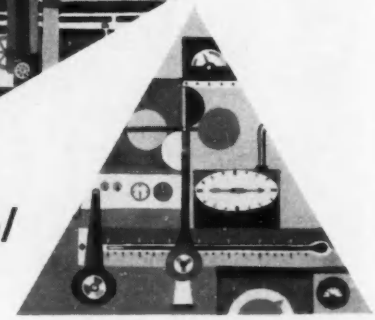
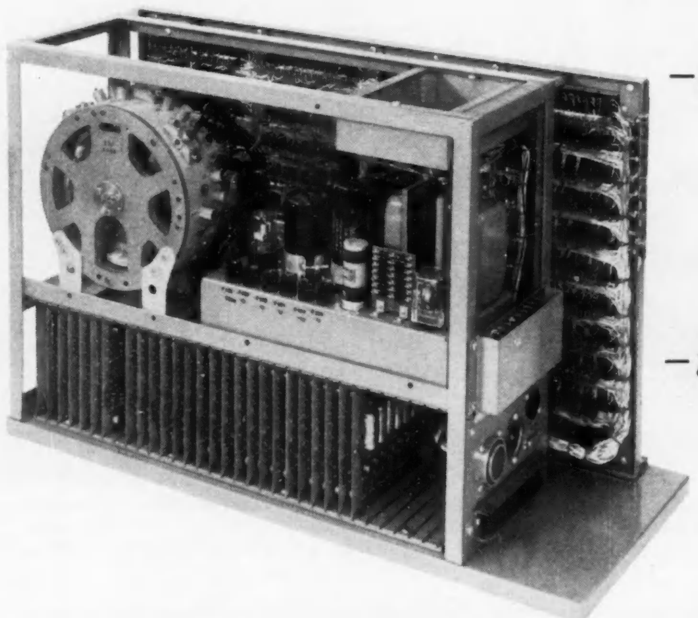
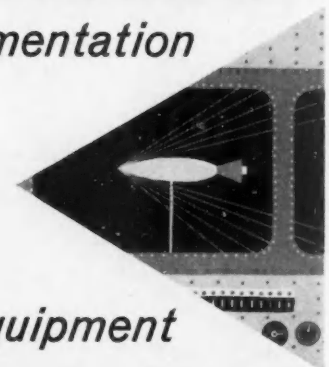


a digital arithmetic center that works with: —process control

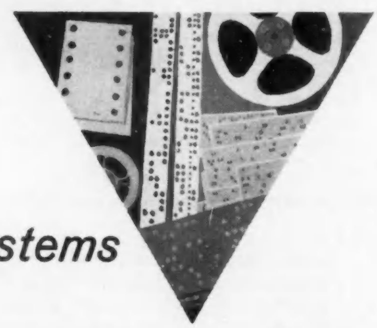




—instrumentation



—test equipment



—data-processing systems

Important specifications include:

- Number System . . . Decimal
- Word Length . . . 18 decimal digits and sign
- Storage . . . Magnetic Drum
- Storage Capacity . . . 16 words per channel, non volatile
  10 channels are available
  2 channels are supplied as standard equipment
- Instructions . . . Multiple Address
- Input of Data . . . Unique pulse per digit or binary coded decimal
- Input of Instructions . . . DC voltage to proper connector pin(s)
- Output . . . Unique pulse per digit or binary coded decimal
- Size . . . Length 28", height 19", width 13"
- Weight . . . 97 lbs.
- Power . . . 117 VAC ±10%, 150 watts maximum, 60 cycle, single phase
- Construction . . . Modularized, solid state, plug in components

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You name the application, and Clary's new arithmetic center—the DAC-2500—will fit it.

FLEXIBLE. This unit performs arithmetic, logical, and memory functions with phenomenal speed and accuracy . . . works with punch card and tape devices, analog to digital converters, X-Y plotters, printers, and other input and output equipment.

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Clary CORPORATION,
COMPUTER DIVISION
San Gabriel, California

Systems Talk Through Common-Language Pool

THE GIST: How to integrate and control a large instrumentation complex is an old problem that has become newly important and more difficult with today's high data volumes and information rates. The system developed by Lockheed and Beckman for real-time control of a large number of different data equipments is called PICE (Programmable Integrated Control Equipment) and is now being installed at two Air Force data centers. In these installations PICE will integrate high-speed data links, low-speed teletype links, tape transports, radio telemetry links, large high-speed digital computers, various operating consoles, rf command transmission links, tracking equipment, a timing system, analog displays, digital displays, plotting boards, and more. The PICE system concept uses a high sampling speed and stored-program access to a common-language information pool to integrate all these asynchronous, multilanguage instruments in a solution which should have wide usefulness in business and industry as well as satellite control.

WARD ELLIS, Lockheed Missile and Space Div.
GORDON R. JUSTUS, Beckman/Systems Div.
WILLIAM D. BELL, Mellonics

Integrated control of equipments having different languages and different data rates must be recognized as basically a problem in providing ready communication between equipments. Until the communication difficulties are resolved, there is no hope for integrated control.

Communication has five requirements in an ideal real-time control system:

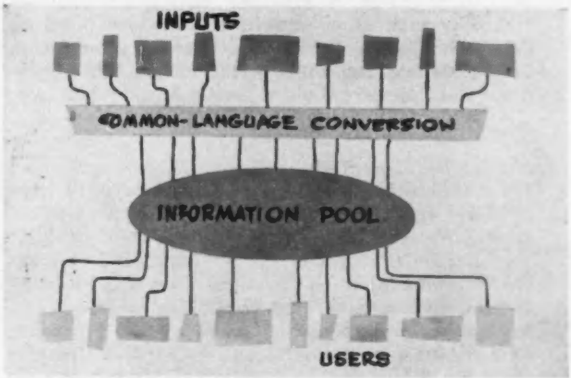
- All data should be in a *common language*
- All data should be *instantaneously available*
- All data should be *available to all users*
- Access to data should involve *no priority problems* for qualified users
- Access to data should involve *no synchronizing problems* that constrain operations.

Three solutions are possible

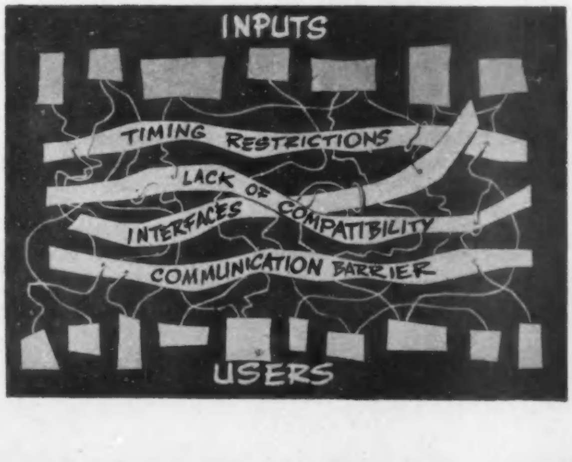
Three basic approaches can be taken to a real-time problem with the five requirements just stated:

1. THE BLACK BOX APPROACH. Instrumentation may be planned in terms of special-purpose black boxes, each designed to meet specific system requirements. This solution is poorest when instrumentation must be quickly and easily adapted to changes in the system.
2. THE G-P COMPUTER APPROACH. A general-purpose computer can be used for controlling opera-

Conventional Information Flow



vs. Buffered Information Flow



tions and thus avoid the lack of flexibility in the black box approach. It is hard to demonstrate convincingly in advance of actual operations that this approach generates many problems of its own in large real-time control applications. This is because any application can be singled out to show successfully how the computer can easily handle the problem. But when the entire job is programmed and placed upon the computer, the limitations of memory capacity, speed, simultaneous demands for input and output, timing restrictions, and so forth, all combine to make the use of the general-purpose computer for control a difficult problem.

3. THE PICE SOLUTION. The next generation of computers will be faster than today's by orders of magnitude because they will use the principle of parallel operation; and faster circuits and novel components will contribute far less. Parallel operation means that all information flow is not bottlenecked through a single equipment but instead that a battery of parallel equipments is harnessed to work as a team. The PICE concept provides special flexible equipment (for coupling with a large number of input/output devices and automatically controlling the information flow through the system) which operates in parallel with a general-purpose computer (which does all computing and will make decisions and take control as programmed).

Thus, both PICE and the computer devote their energies to the areas where they are most efficient. Instead of the computer having to digest the entire data mass, it must cope only with information actually needed, which it gets by directly addressing PICE. PICE, meanwhile, controls all information flow with a bare minimum of stored-program data. This simple automatic control of information flow contrasts strikingly with the ponderous program a computer would need to do the same job.

The PICE system concept

Figure 1 shows the information flow situation for a typical instrumentation complex. Users have difficulty in gaining access to the data because of timing restrictions, lack of language compatibility, organizational and equipment interfaces, and assorted communication barriers. How can this information flow picture be changed to provide common-language data instantly available to all users, with no priority problems and no synchronizing?

Figure 2 supplies an answer to this problem in terms of a buffered information pool. Now all inputs go through a common-language conversion and store their data digitally in the information pool. Data users always have access to data by consulting the information pool rather than the original source of data.

The information pool in Figure 2 has a good analogy in the stockbroker's quotation board. There are fixed locations on the board for displaying the current prices on stocks, bonds, and commodities. As fast as price changes are received via the broker's various automatic communications links, the data displayed on the board are updated to reflect the latest information. All users in the vicinity of the quotation board have simultaneous access to any or all data. Remote users of the data get their information by communication links from those people in visual contact with the board.

From a data systems concept the broker's quotation board has three important characteristics:

- It is a buffer between input sources of data and the users of data
- It is a common-language information pool
- It is automatically updated.

PICE is the implementation of these concepts.

Speed is the key

PICE is basically a high-speed memory with its own internally stored program and means for coupling to other equipments. In the simplest possible terms a PICE integrated instrumentation system looks like Figure 3. PICE's most important function in such systems is transforming a large number of completely asynchronous data sources into a form where all data are synchronously available to all users. Yet this transformation is made without synchronizing the information pool itself with the devices that update the pool.

The key to PICE operation is its speed. The information pool in PICE is a ferrite core store with an access time of 6¼ microsec for writing or reading out of data. There are 160,000 accesses to the information pool in a single second. Thus, the information pool is able to scan all the access functions (input or output, in an arbitrary pattern under direction of the stored program) at a rate so much faster than the change of the data itself that it can guarantee that all data will be transferred into the pool without loss of information.

PICE's means of communicating with asynchronous devices is illustrated by Figure 4. The top line

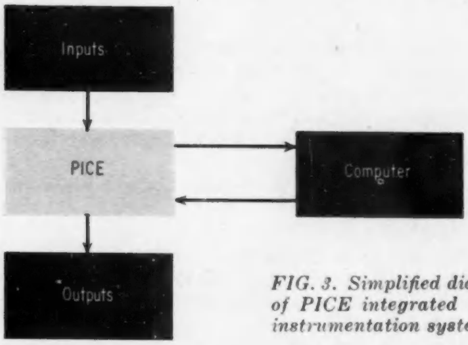


FIG. 3. Simplified diagram of PICE integrated instrumentation system.

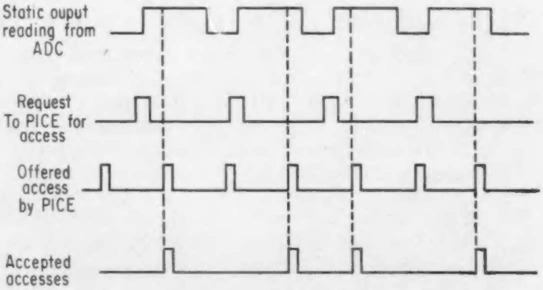


FIG. 4. PICE communicates with asynchronous devices, offering access to its own memory at a high enough rate to sample all signals (requests) from the devices.

shows a static output reading from an analog-to-digital converter, or the period that each digitized reading appears in the output register of the ADC to be read. Such an output could come from ground station telemetry equipment, for example.

The second line in Figure 4 shows the timing with which the output of the ADC requests the opportunity of communicating with PICE. Thus every time there is a new reading in the ADC, this signal says "I want to talk to PICE".

Line 3 shows the timing with which PICE offers accesses and this is controlled by the ordering of the control data in PICE's control memories. The timing of these pulses is very accurate. The timing of the access requests from the outside equipment need not be accurate, but PICE must know the maximum rate at which data will be transferred.

The bottom line shows the timing with which PICE accepts data. There were four signals to be accepted by PICE and each of the four were accepted. To do this, however, PICE offered more than four access cycles. PICE was operating at a rate enough faster than the rate of change of input data that it could guarantee that all data would be transferred into the information pool.

This technique, which depends upon high speed, permits transferring data between communicating devices and PICE without synchronizing control.

Stored program controls communications

Figure 5 shows that PICE has two program memories which can operate simultaneously, making higher system speeds possible. The information pool is shown at the right and can store either data or indirect addresses. The access function registers at the bottom consist of toggles and control lines which are used to interconnect PICE and external equipment. The timing and control circuits in the center operate under the direction of the stored programs in program memories 1 and 2 to select one access function register at a time, connect it to the information pool, and either write data into the pool or read data out of the pool.

Figures 6 through 9 explain the operation of PICE's stored program control scheme. In Figure 6 an 80 kc source of pulses from the master clock (240 kc) is counted in the access sequence counter which is preset to gate to the address register of program memory 1. Thus, after the preset initial address of the sequence (sigma as shown in Figure 7) sequential control words are read out of memory one every 12½ microsec.

In Figure 8, program memory 2 stores 256 words corresponding to 128 possible access function registers (AFR's) plus 128 associated with transfer of data within the information pool. As shown in Figure 7, an 8-bit address is contained in the word read from program memory 1. This address selects a second 30-bit word to be read from program memory 2 (Figure 9). These words determine PICE operations during a single 12½ microsec period.

Each of PICE's 80,000 access cycles per second is programmed as has just been shown, and during each access cycle PICE determines four things:

- Which input or output device is connected to the information pool

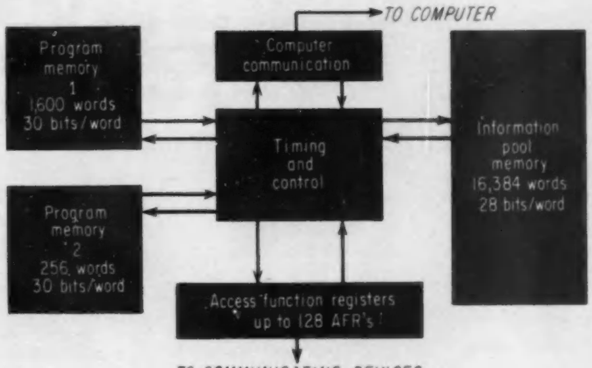


FIG. 5. Block diagram of PICE shows two program memories, the information pool, timing and control circuits, and up to 128 access function registers for communicating with outside devices.

- Which serial address will be used for reading into or reading out of the information pool.
- Whether indirect addressing is necessary. In indirect addressing PICE goes to the information pool to find another address, which is then used for reading or writing the data. Indirect addressing makes it possible to handle random sequences of data. All decommutating of telemetry data is done by PICE without special ground-based decommutating equipment for each telemetry station.
- Whether the selected access function will read into or write from the selected address in the information pool. Most equipments will do one or the other. Some equipments, such as terminal devices for high-speed data links, can do either.

Every 12½ microsec PICE makes the four determinations listed above, communicates with some external equipment, and transfers up to 24 bits of data to or from the selected device. Over 2 million bits of data can be transferred every second.

PICE also permits a maximum of 80,000 computer accesses during the same second. This is done by interconnecting the computer's core memory with PICE's core memory at any time that PICE is not using its indirect addressing capability. The computer used with PICE will be Control Data Corp.'s 1604. Because the 1604 uses buffered input-output channels for PICE communication, data transfer with PICE is asynchronous with respect to the computer program, which therefore operates effectively in parallel.

Thus, PICE communicates with all its coupled devices between 80,000 and 160,000 times per sec.

The access function registers control interconnections

PICE access function registers, or AFR's, are used to interconnect communicating devices with PICE. Each AFR provides a 24-bit data register and up to 20 interconnecting control lines.

PICE's basic operating premise is that control comes from the outside communicating device. PICE simply does what it is told to do and this control is established over the 20 interconnecting lines. Each equipment does not actually use all 20 lines, but rather only those lines pertinent to its

FIG. 6. Program memory 1 control.

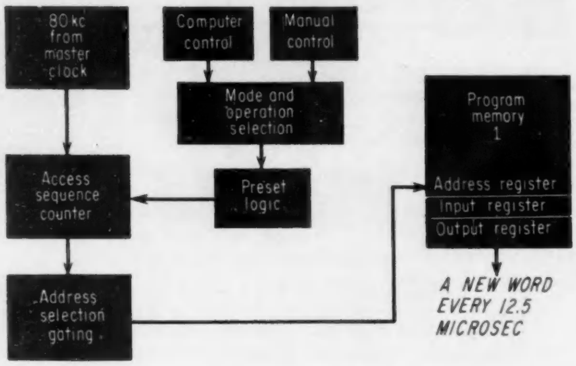


FIG. 7. Control word 1.

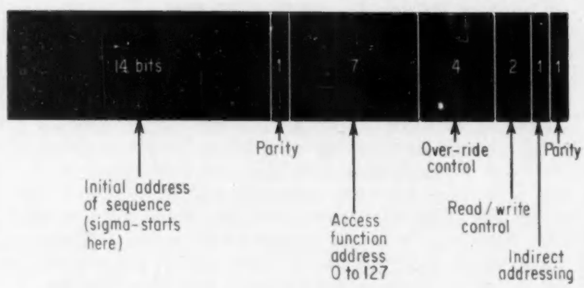


FIG. 8. Program memory 2 control.

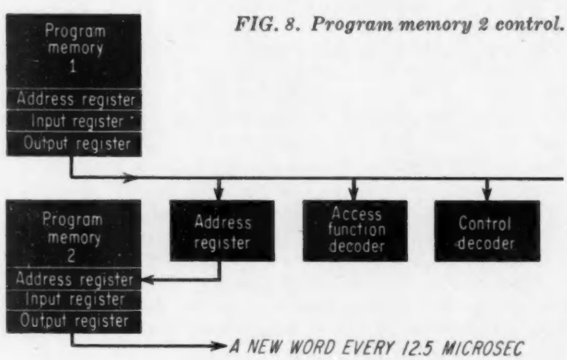
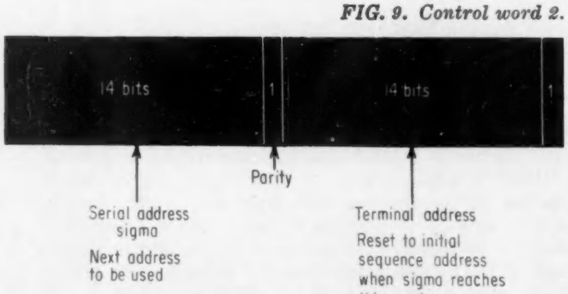


FIG. 9. Control word 2.



operation. The remaining lines are unused.

The first three control lines are concerned with requests from outside PICE. A request can come at any time. Control line 1 signals that the access function desires access to the information pool. Control line 2 tells the AFR if data are to be entered in parallel, and control line 3 tells if data are to be entered serially.

The access function registers accept either bit-serial data entry, parallel data entry, or combination parallel-serial entry. As an example of the last, a four-bit binary coded decimal number can be entered in parallel and then shifted over four places to allow room for the next entry of four bits. This continues until six binary coded decimal numbers are entered into a 24-bit register.

To complete a request from outside, the communication equipment must supply signals on line 1 and either line 2 or line 3. Line 4 then signals PICE's closed-loop reply to the above requests.

The next four lines specify operations to be carried out by PICE. Line 5 is used by the outside device to specify whether data are to be read from or written into the information pool, line 6 whether direct or indirect addressing is to be used, line 7 signals when sigma is to be incremented (effectively it says "Use the next serial address reserved for this function"), and line 8 resets sigma back to the starting address (thus a sync-lock signal can establish the start of a decommutating pattern).

Lines 9 and 10 are used by PICE to signal that a parallel or serial entry, respectively, has been completed. Line 11 signals every time PICE communicates with the AFR and thus whether or not the access cycle is allowed. Line 12 signals that this AFR is selected and can be used by the communicating device for controlling new entry into the AFR. Line 13 signals that the access cycle to the AFR has been completed. Line 14 signals every time the sigma address is set back to its starting address. The last four signals are not often used.

Control lines 15 and 16 are concerned with internal checking and tell external equipment of any failures in reading programming data from memories 1 or 2, and of data transfer failures to or from the information pool, respectively.

Control lines 17 through 20 make PICE timing signals available to coupled equipments. PICE's timing signals can be used to synchronize communicating equipments with PICE exactly when this may be desirable, and can also be used by external equipments to control their own functions.

Input restrictions are lenient

The restrictions placed upon the signals that the outside device must furnish are very lenient. This is important for easy equipment integration. Rise time and pulse shape are of no importance, for example, because there is no ac coupling. All that is necessary are steady-state signal levels of 0 to ½ volt for a binary zero or false signal, and minus 5 to minus 12 volts for a binary one or true signal. There is a requirement on the minimum time that a signal must be supplied: on some signal lines the minimum duration of a signal is 5 microsec and on others it is 15 microsec.

Servoed Oscillator Outputs Counted for Phasemeter

A. BERNSTEIN
Cubic Corp.

A unique phase measurement technique that involves counting the outputs of two oscillators servoed to the input signals makes possible a new phasemeter for angle and distance measuring equipment. Developed for tracking of aircraft and missiles, the device converts phase information to digital form by converting a reference signal and a data signal to digital numbers and then subtracting their instantaneous values.

The new digital phasemeter consists of two electronic servos and a processor, Figure 1. The inputs are both at the same frequency (nominally, 1 kc) and consist of a reference signal (with a phase angle ϕ_1) applied to one electronic servo and a data signal (phase angle ϕ_2) applied to the other. The electronic servos convert the analog phase information into digital numbers. Subsequent mathematical operations are accomplished in the processor, which also contains an output register for display and readout.

The electronic servo shown in Figure 2 is a phase-locked feedback system including an area phase detector, an operational dc amplifier with servo compensation networks, a voltage-controlled oscillator (VCO), and a binary scaler. The phase detector may be considered to be a gate which passes the input signal when the feedback signal is positive. The average output of the phase detector is proportional to the cosine of the phase angle between the input signal and the feedback signal.

Forgetting the action of the scaler for the moment, when the feedback square wave from the VCO is precisely in quadrature with the incoming signal, the dc output of the phase detector is zero, as the positive and negative portions of the incoming signal are equal during the positive half-cycle of the 1-kc feed back (shown in the shaded portion of the sine wave in Figure 2). When the phase relationship deviates from 90 deg, the output of the phase detector averages a dc voltage whose polarity depends on the sense of the phase variation. This output is used as a servo error voltage; it is greatly amplified and impressed upon the VCO to change the latter's phase and restore the quadrature relationship at the phase detector.

The output of the VCO is thus servoed to the incoming signal, and the positive-going edge always occurs at the plus 90-deg phase point of the input signal. This established a reference point on the input, as in a zero-crossing detector.

Each of the two signals whose phase difference is to be measured is fed to an identical electronic servo. In each servo the feedback square wave will be 90 deg out of phase with the input. Therefore, the phase difference between the square wave output from the reference VCO and the square wave output from the data VCO will be the same as between the two sinusoidal inputs.

In order to improve the signal-to-noise ratio, narrow dynamic bandwidths are utilized and the electronic servos switch bandwidth automatically. Thus the servos have a 10-cps bandwidth during target acquisition and then switch to a 1-cps bandwidth for target tracking. If signal lock is lost, the bandwidth automatically returns to 10 cps for reacquisition.

A/D conversion

The phasemeter's method of analog to digital conversion can be seen when the binary scaler is considered. Now the center frequency of the VCO is a binary multiple of the input signal frequency with the binary scaler inserted between the VCO and the phase detector. The binary scaler divides the VCO frequency (Nf) by N, the output of the scaler, which is at the same frequency as the incoming signal and is used as the feedback signal to the phase detector. The VCO frequency is 1.024 Mc; the binary scaler divides the frequency by 1,024,

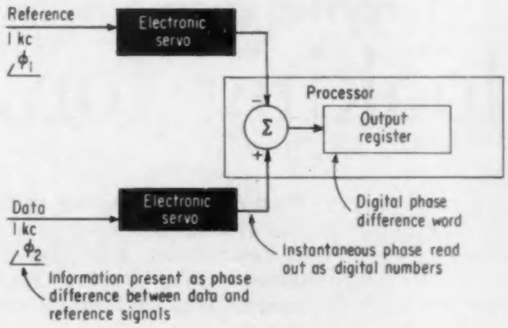
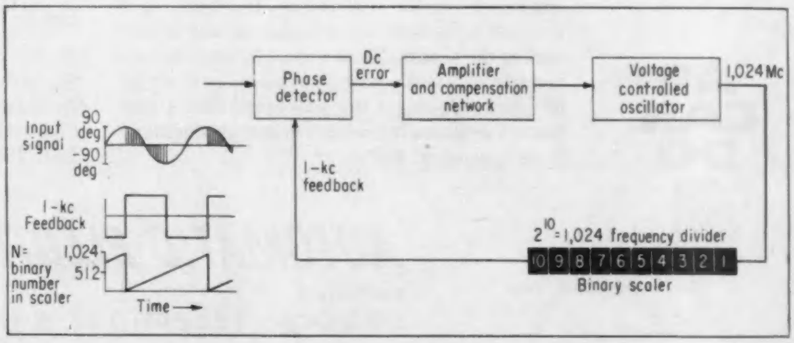


FIG. 1 Outline of phase measurement system shows how input phase angle is compared to reference.

FIG. 2. Detail of electronic servo shows input and feedback waveforms and how binary scaler operates.



and the 1-kc output is used as the feedback signal. The servo with the scaler operates exactly as without; magnitude of the count in the binary scaler at any instant is a measure of the instantaneous phase of 1-kc input.

When the 1-kc feedback signal crosses zero in the positive direction, the stages in the scaler go from all ones (maximum count) to all zeros (minimum count). As the phase of the input signal changes, the scaler begins to accumulate counts from the VCO. When the input signal crosses zero in the negative direction, the scaler count is 256; when the input signal is at minus 90 deg, the count is 512. The scaler continues to accumulate counts until the signal reaches plus 90 deg, when the scaler again goes through maximum count (1,024) and resets to zero. Thus the magnitude of the count always represents the phase of the input signal, measured from its last 90 deg point. Since each scaler contains, as a binary count, the instantaneous phase (with respect to its own 90-deg point) of the input sinusoid, the count difference between the two scalers is directly proportional to the phase difference between the two input signals.

As shown in Figure 2, the VCO frequency is 1.024 Mc; since the input signal is 1 kc, there are 1,024 cycles coming from the VCO and counted by the scaler during each 1-kc period (1 millisec). Each input cycle is effectively divided into 1,024 parts.

Memory Logic Allows Stepping Motor to Catch Up

R. A. VICTOR
University of California
Radiation Lab.

Pulsed stepping motors are sometimes limited because of their relatively long mechanical response time (10 to 100 millisec). This limitation can be overcome if a suitable memory device is used to remember the number of steps required and if a suitable feedback is supplied to insure that all of the command signals have been acted upon by the stepping motor. Such a scheme permits the command signal rate to exceed the mechanical response time of the stepping motor without danger of over-all positional error. However, this method is not applicable if it is necessary to maintain a 100 percent phase relationship between command signals and mechanical output of the stepping motor.

In the system shown in Figure 1, each command signal adds 1 to the counter, and each step of the motor subtracts 1 from the counter via the feedback generator. The output of each section of the counter is fed into a buffer whose output is one leg of a two-leg gate, the other leg being a clock pulse of a frequency compatible with the stepping motor response time. As long as any section of the counter registers 1, the motor will be stepped one step for each clock pulse. Since each step of the motor will subtract 1 through the pulse generator, the operation will continue only for the exact number of command signals or until the counter reads all zeros. If a short capacity counter is used, it is possible to use an indicated overflow to sound an alarm.

A more elaborate application for this system would be one where bidirectional stepping of the motor is desired. Figure 2 shows a bidirectional pulse generator used for position feedback. The generator developed for this application is simple and inexpensive.

Figure 3 shows such a pulse generator designed for use with a stepping motor having 90 deg steps. Since the pickup coil is mounted 45 deg from the steady state position, any 90-deg rotation in either direction will generate a voltage pulse whose polarity is dependent upon the direction of rotation. The amplitude of the voltage depends upon the speed of rotation and the distance between the coil and the magnetic pole.

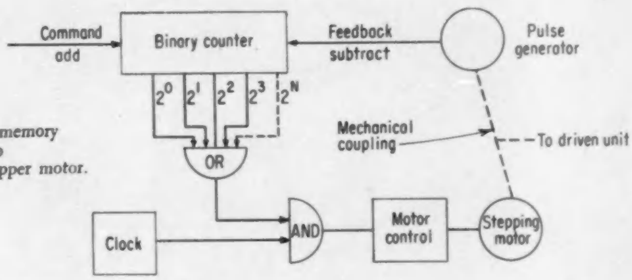
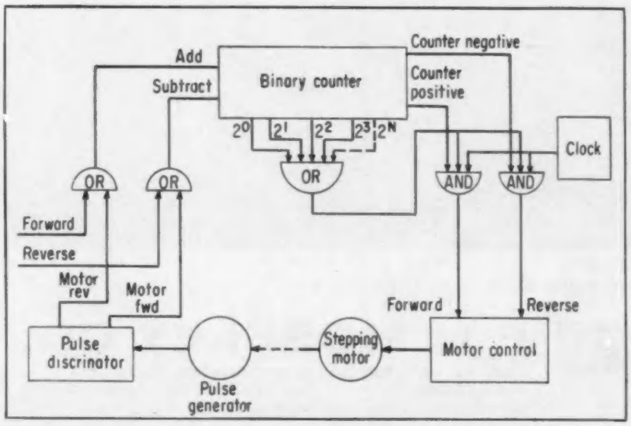


FIG. 1. Binary memory device applied to unidirectional stepper motor.



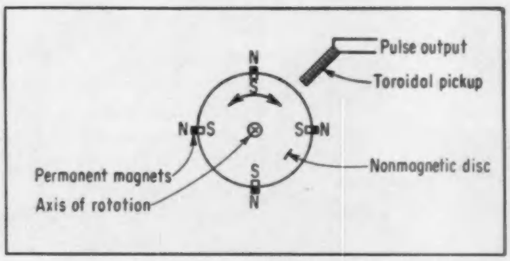


FIG. 3. Pulse generator used in system of Figure 2.

FIG. 2. Bidirectional system shows how forward pulses are added, reverse pulses subtracted and motor reverse steps are added, forward steps subtracted in binary memory system.

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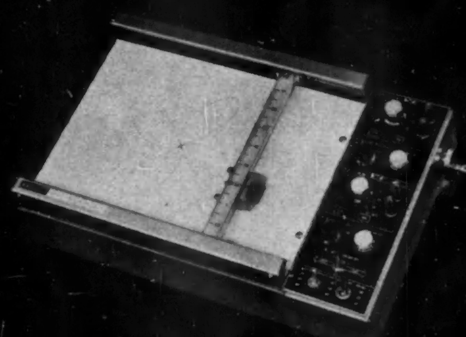

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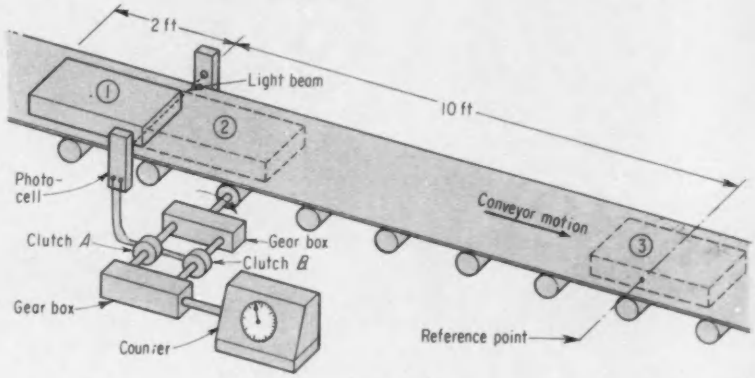


The control system shown here accurately finds the center of any item moving on a conveyor line. This simple electromechanical device signals when the center of the item is at some predetermined reference point. The system is particularly useful when it is necessary to find the centers of items with random lengths or to position an item on some destination line so it can be moved off the conveyor.

For example, assume it is necessary to position the center of a 2-ft long box, at a reference point 10 ft beyond the sensing element. The sequence is as follows: the leading edge of the box breaks the beam to the photocell (position 1). This energizes electric clutch A which in turn drives the counter. The gear boxes are so arranged that input through clutch A will turn the counter at precisely one half the speed of the conveyor. The instant the box passes, allowing the beam to hit the cell again, clutch A disengages and clutch B engages (position 2). Clutch B is geared to drive the counter at the same speed as the conveyor. (Motion of 1 ft registers 1 ft on the counter.) When the box has reached position 2, it has moved 2 ft, but the counter has registered only 1 ft, or half the length of the box.

The box then moves the remaining 9 ft to position 3. At this point the counter reads 10 ft (1 ft from clutch A operation and 9 ft from clutch B) and gives a signal indicating that the center of the item is at the reference point. At the same time this signal goes out, the counter resets itself.

The distance between the sensing element and the reference point is the maximum item length the system is able to take.

Hydraulics Half-Add Binary Numbers

F. D. EZEKIEL
American Measurement & Control

R. J. GREENWOOD, III
Mass. Institute of Technology

Laboratory work at MIT has developed the form of a fluid logic element that can be used for adding binary numbers. Actually the devices so far have been used only for half-adding. That is, only the carry operation of addition is performed by the elements. The elements have no moving parts, operating on the principle of momentum exchange between two fluids as they impinge on each other. Models were built of Plexiglas, and hydraulic fluid was used.

Figure 1A shows how fluid streams can be added. If stream A = 1 and B = 0 (presence and absence of flow), the output of C can be called 1. If the signals of A and B are reversed, the output, or sum, is the same. On the other hand if both A and B have a signal, Figure 1B, flow from the other output tube D can indicate the sum of 1 and 1. If the two streams are not of equal strength, the two output flows will vary accordingly. Models have been tested with flow ratios ranging from 7 to 1 up to 20 to 1.

These elements have been cascaded as shown in Figure 2 to produce a binary half-adder. The circles represent simple button valves that have been set by external logic to represent the addition of two binary input signals, 0101 and 1101. The hydraulic logic element performs the carry operations, giving the sum 10010. It is interesting to note that to make the device work, a method had to be incorporated to bleed part of the flow back to the sump. This is done only in the case when a carry occurs, insuring that all fluid streams have equal magnitudes. The mechanism is a simple orifice located on the bottom of the Plexiglas model.

These elements could be combined to form a complete adder, so that both the simple addition and the carry addition would be done.

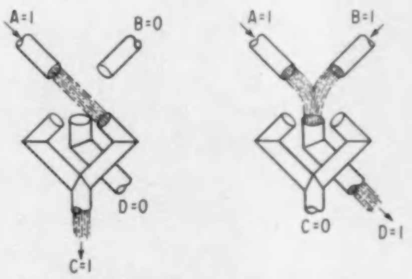


FIG. 1. A—If only one of the fluid streams has a signal, the output will be added to give a sum of 1. B—If both streams equal 1, the output will be their sum. A difference in magnitude of two streams will result in a corresponding flow ratio between the two output streams.

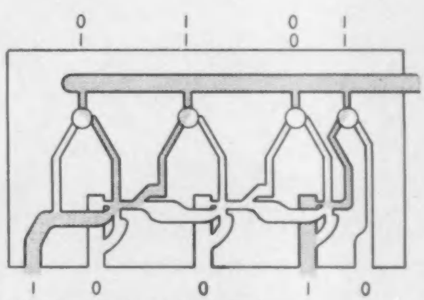
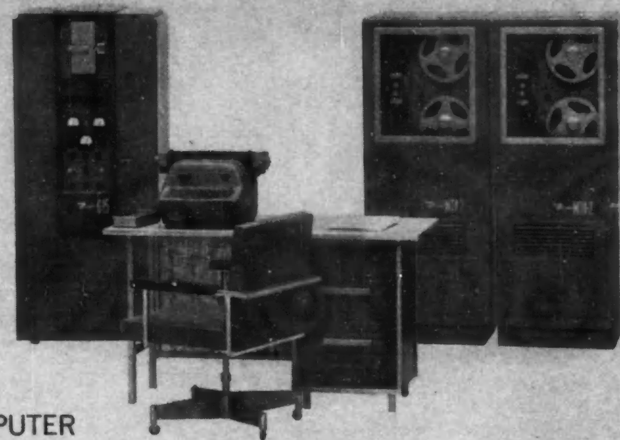


FIG. 2. Method of adding two binary signals, 0101 and 1101. The setting of the button valves (circles) represents the primary addition, the logic element described here performing only the carry operations.



Recorder Checks Automobile Performance

S. H. COOMBS
S. Sterling Co.

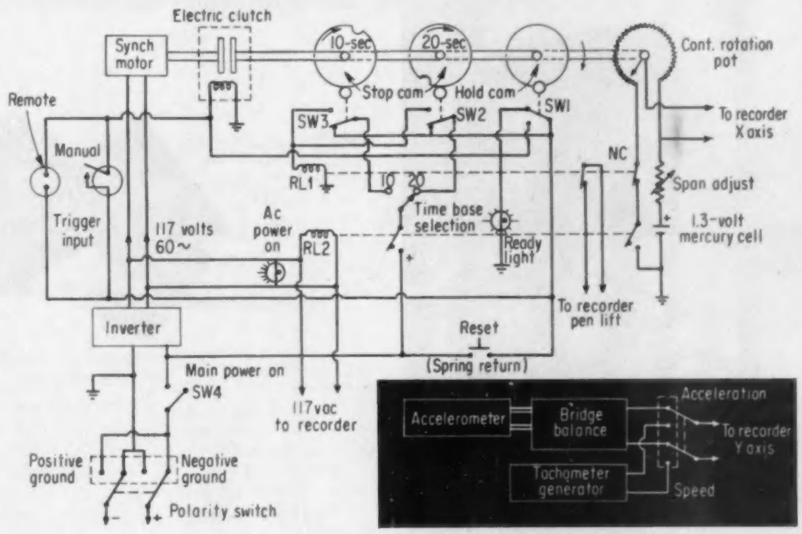


FIG. 1. Automatic performance measurement circuits. Diagram at lower right shows how the system can be switched between acceleration and velocity measurements.

Trailing a fifth wheel behind a vehicle is a common method for determining velocity and acceleration characteristics. But a unique recording circuit used with the fifth wheel gives better results than the former manual method of transcribing the fifth wheel's voltage signal. Tedious graphical differentiation is no longer necessary, and since recordings are automatic, observer reaction time cannot introduce error. Also the device records wheel spin, shift point, and other irregularities that did not show up on conventional plots.

To get velocity readings, a tachometer is mounted on the fifth wheel. As the car moves, the tachometer generates a dc voltage proportional to the car's speed. The dc voltage signal is the Y input of an X-Y recorder, where a pen, calibrated in miles per hour, makes a plot of velocity vs time. By replacing the tachometer with a strain gage accelerometer and the necessary balance circuitry, a plot of acceleration vs time is similarly obtained.

Figure 1 shows the unit with a laboratory-built time base generator. A 10-kilohm continuous rotation potentiometer, driven by a synchronous motor, supplies the X-axis input. A 1.34-volt exciting voltage comes from a mercury cell. As the motor drives the potentiometer arm, the recorder receives a voltage that increases linearly with time.

Because of the inertia of the motor and potentiometer when starting from rest, results are more accurate when the motor runs continuously and engages the potentiometer through an electric clutch at the start of a cycle.

How it works

The operating procedure can be followed in Figure 1. To prepare for a test run the main power on switch *SW*4 energizes the inverter and relay *RL* 2. The inverter supplies ac for the time base synchronous motor and the X-Y recorder. Relay *RL*2 also readies the time base circuits. Vehicle battery power supplies the unit through a polarity reversing switch to insure that the chassis and vehicle frame are at the same potential. The length of the test run, either 10 or 20 sec, must also be preselected. These time intervals were chosen empirically.

The unit is triggered either by the accelerator pedal switch or a manual switch on the console. This energizes the electric clutch that is attached to the shaft carrying the potentiometer and the three cams: 10-sec stop, 20-sec stop, and hold. As the shaft starts to revolve, the hold cam allows the normally open *SW*1 to close, thus holding the clutch energized.

At the end of the preselected time, one of the timing cams opens *SW*2 or *SW*3, depending on the time base selection, thus operating *RL*1. This in turn opens the potentiometer X-axis circuit, deenergizes the clutch, and lifts the pen from the recorder.

To zero the time base cams and repeat the cycle, the reset switch is held in, energizing the clutch through switch *SW*1 until the hold cam allows *SW*1 to open. This turns on the ready light and opens the clutch circuit.

Figure 2 shows an acceleration vs time plot for a late model production automobile. The initial acceleration is slightly over 0.55; the marked change in acceleration at the shift point is the result of an incorrectly adjusted automatic transmission.

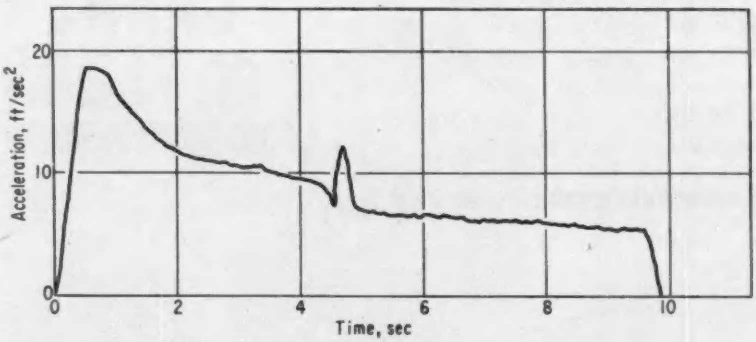
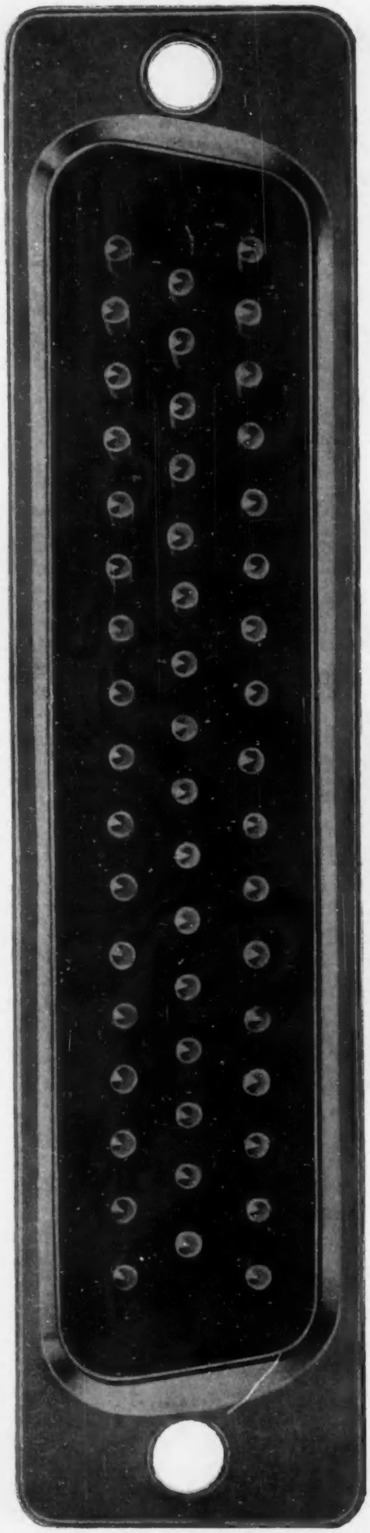
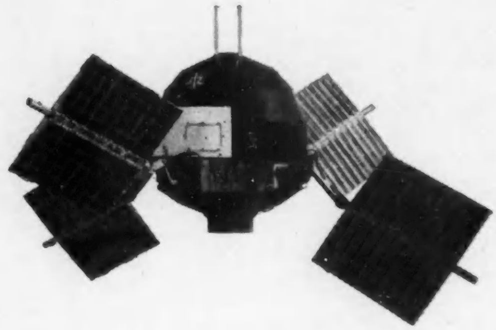


FIG. 2. Acceleration vs time for a 10-sec test of a late model passenger car. Irregularities in the curve are due to fifth wheel hop and noise.



THREE AND ONE-HALF TIMES ACTUAL SIZE.



NEW PRODUCTS

MATCHED SIZE 5 LINE now includes all components.

Available from one supplier for the first time is a complete matched line of Size 5 (nominal $\frac{1}{2}$-in. diam) rotating electromechanical components. A unique design technique allowed all components to be designed around normal 26-volt excitation and resulted in better performance.

The synchro part of the line was designed using a new completely automatic computer design optimizing procedure. The computer, an LGP-30, was programmed to optimize the product of flux and Q by solving an expression involving some 70 differential equations. The program is called completely automatic since the computer was not asked individual questions (what would happen if? . . .) but was given all the parameters plus external constraints (outside diameter, stack length, impedance level), and it plunged ahead until an optimum design was printed out. The results involved optimum dimensions, wire sizes, number of turns, air gaps, tooth widths, bore diameters, and core thicknesses.

By the use of this design technique, said to be the first such automatic procedure applied to design of these components, the Size 5 synchros have been made electrically compatible with larger units.

Included in the matched line are a servomotor and low null damping motor-generator (right) and a standard damping and a high signal to noise ratio damping motor-generator. The synchro components (right) include a control transmitter, control differential, high and low impedance resolvers, and high and low impedance control transformers. Typical characteristics of the high impedance control transformer, for instance, are open circuited rotor impedance, 2,390 ohms $\angle 73$ deg; open circuited stator impedance, 550 ohms $\angle 74$ deg; and transformation ratio (stator-rotor), 1.765 $\angle 12$ deg.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

Circle No. 309 on reply card

Servomotor

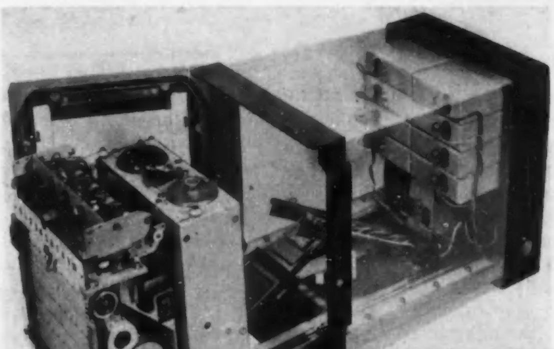
Stall torque: 0.1 oz-in.
Power input: 1.7 watts/ϕ
Theoretical acceleration: 40,500 rad/sec^2
No load speed: 9,500 rpm
Rotor moment of inertia: 0.175 gm-cm^2
Length: 0.968 in.
Weight: 0.68 oz

Synchro

Max null voltage:
44 mv rms
41 mv fundamental
Max error: 10 min
Length: 1.24 in.
Weight: 0.9 oz

Low null damping motor-generator

Output: 0.1 volt/1,000 rpm
Null: 10 mv rms
Stall torque: 0.1 oz-in.
Power input: 1.5 watts/ϕ
Theoretical acceleration: 28,600 rad/sec^2
Rotor moment of inertia: 0.247 gm-cm^2
Length: 1.507 in.
Weight: 1.05 oz



INNOVATIVE POTENTIOMETER uses strain gage, not slidewire.

In this new ElectroniK 17 potentiometer a rugged, long lived strain gage rebalancing element has been substituted for the classical but often troublesome slidewire. In addition, complete redesigning and repackaging of this widely used type of instrument means reduced size, ease of calibration, and simple, fast changeovers of basic instrument functions in the plant. Particular benefits to the customer claimed by the manufacturer are a considerable price reduction—perhaps as much as one-third saving compared with its Class 15 potentiometer—and the ability to mount two ElectroniK 17's side-by-side on a 19-in. rack.

Heart of the Class 17 potentiometer is the four-wire Stranducer strain gage element which electrically re-

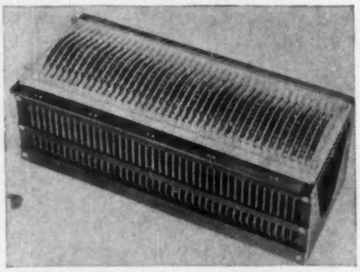
balances the instrument. The wires vary in resistance in proportion to the applied tension. Connected in a bridge circuit, the strain gage controls the magnitude and polarity of the feedback voltage in the measuring circuit. The Stranducer is linked mechanically to the balancing motor through sector and strap motion-reduction stages and a drive cable. When the recording pen moves through its full 6-in. span, the wires stretch only 0.012 in. Many Stranducers have been tested through several million cycles each during the development of this instrument, and plans have been made to cycle each production Stranducer several million times before inspection and installation into the instrument.

The Class 17 line includes two circular scale instruments—a one-pen recorder and a one-pointer indicator—and a one or two-pen strip chart recorder. To these basic potentiometers can be added either on-off or continuous control. On-off control is obtained through integrally mounted sets of contacts (and narrow deadband relays) whose zones can be easily and sensitively set from the front panel. Once set, the zones float with the main index setting. Additional, nonfloating contacts can also be installed. Continuous control is available by connecting the potentiometer to any of the manufacturer's standard controller lines.

The potentiometer's amplifier can be obtained in either a vacuum tube version (with a power transistor) or a completely transistorized version at extra cost. Careful attention to electronics design offers accuracy within ¼ percent; 0 to 5-mv minimum span as standard, with optional 0 to 1-mv span; common mode noise rejection of up to 150 volts at 60 cps; elimination of loop signals induced between primary element and instrument input; and a variable source impedance up to 25,000 ohms—all without discernible zero shift, dead spot, or effect on pen damping. Most significant is a single automatic cold junction compensator suitable for all thermocouples and all ranges.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia, Pa.

Circle No. 310 on reply card

DATA HANDLING & DISPLAY



MULTICONTACT SWITCH

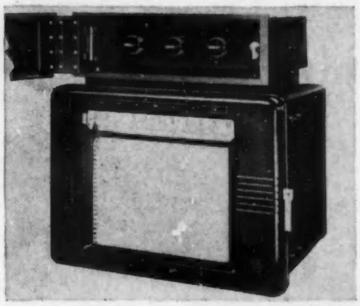
Shown above is one model of a new line of high capacity data switches for multicontact temporary or permanent switching. The unit above has 40 single pole switches which can be manually positioned to select one of 56 contacts on glass fiber printed circuit boards. Knurled edges and high visibility of markings allow rapid setting of messages or programs. Modular construction permits assembly in various forms to meet requirements of manual data insertion for computers, test equipment, process control, etc. Compact design extends only 6 in. behind mounting panel, and switches can be stacked as close as 12 in less than 5 in.—Instrument Systems Corp., College Point, N. Y.

Circle No. 311 on reply card

CRT REMEMBERS 2 HOURS

The phosphor in the screen of this cathode ray tube is able to retain and indicate signals up to 2 hr after they have been received. Within this memory span the tube can present the signals, over and over again, up to a total readout time of 1 min; high infrared energy erases them. Originally developed for a marine radar application, the 10-in. tube is now available for applications where brief, frequent displays and fast erasures are necessary. Tube uses magnetic deflection and electrostatic focus. Price: $110.—Raytheon Co., Industrial Components Div., Newton, Mass.

Circle No. 312 on reply card



NEEDS NO CALIBRATION

This adjustable span and zero recorder features settings on calibrated dials; no external calibration is necessary. Span accuracy is within ½ percent of set value, and zero setting is also accurate to within ½ percent. Span of 1 mv and cross chart speed of 1 sec are standard. Zener diode provides constant voltage. Calibrated zero vernier can be set from 0 to 50 mv of suppression. Span is continuously adjustable from 1 to 20 mv. Amplifier gain is over 1 million.—Barber-Colman Co., Wheelco Industrial Instruments Div., Rockford, Ill.

Circle No. 313 on reply card

DIRECT RECORDER

Six and eight channel 40-mm ink or inkless traces are provided on rectangular or curvilinear charts by these new direct writing recording systems. Units incorporate medium gain dc amplification with basic sensitivity of 10 mv per chart division and frequency response of dc to 120 cps within 3 db at 10-mm peak amplitude, with differential or single ended input. Input impedance is 1-10 megohms. Event and time data recording are available, as is pushbutton selection of chart speeds of 1-250 mm per sec.—Photron Instrument Co., Cleveland, Ohio.

Circle No. 314 on reply card

PLUS . . .

(315) **Amperex Electronic Corp.**, Hicksville, N. Y., has what it calls the world's most complete line of gas-

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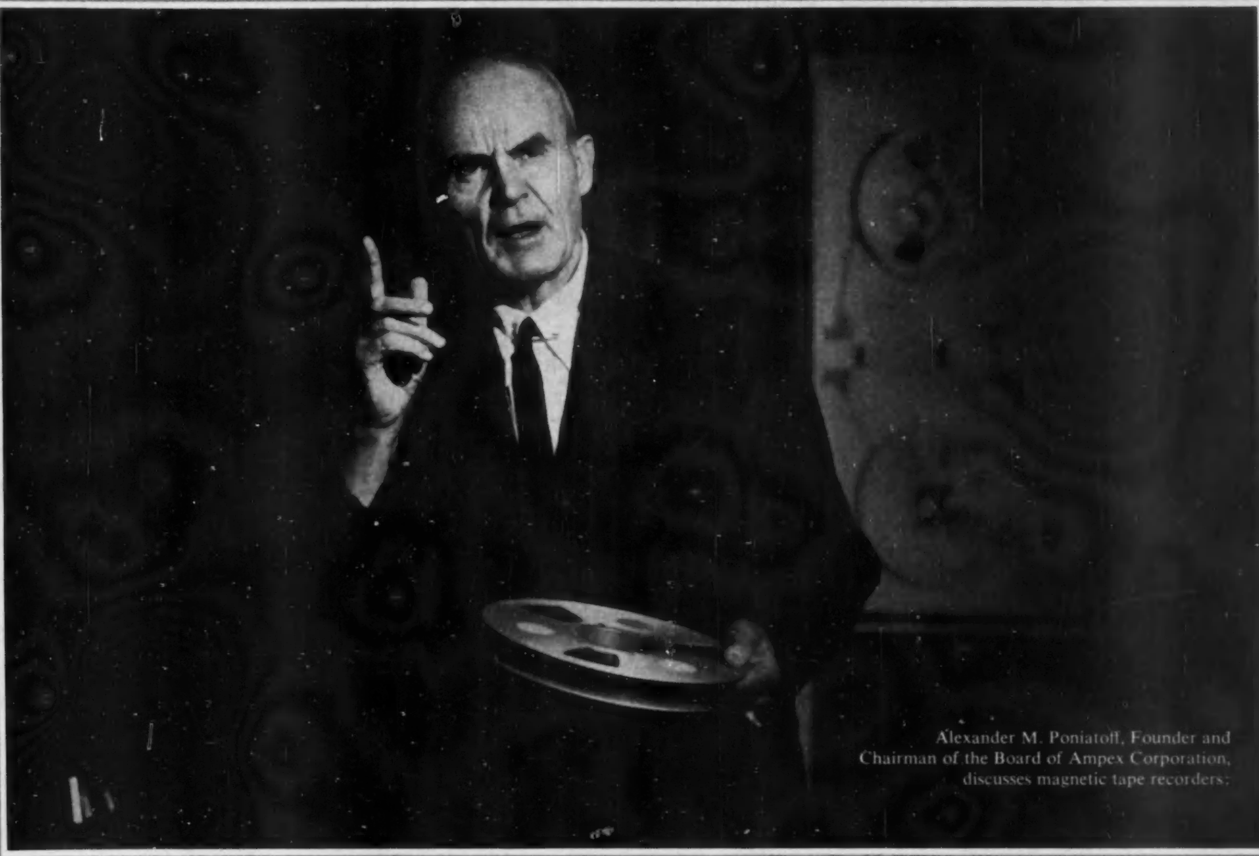

Alexander M. Poniatoff, Founder and Chairman of the Board of Ampex Corporation, discusses magnetic tape recorders.

"Everything Ampex recorders stand for – service, quality, reliability, technological leadership – stems from this attitude.

"The first commercial 'live-quality' audio recorder was developed by Ampex because of the disc record's fidelity drawbacks. Discontent with the capabilities of all data recorders using visual traces spurred Ampex's evolution of special purpose magnetic tape data recorders. Frequency limitations bothered us, so we gave you the 4-megacycle FR-700.

"A need for compact equipment with high performance caused us to introduce the CP-100 – a transistorized 200 kc 14-track data recorder less than 7 cu. ft. small. Striving for versatility and high efficiency, we perfected the FR-600; it records 500 kc at 120 ips – double the previous standard, but still fully compatible.

"And we were even constructively discontented with the way we made these advanced recorders available to you. Now, Ampex instrumentation recorders can be leased or purchased on time as well as outright. You can free working capital for other projects, and invest in your Ampex data recorder as it works for you."

Some significant specifications:
AR-300, FR-700: 10 cps to 4 mc ±3 db; 12½ and 25 ips record and playback. FM recording. Two data, two auxiliary tracks. 2" tape, 10½" reels. AR-300 airborne record only.
CP-100: 300 cps to 200 kc ±3 db at 60 ips; 60, 30, 15, 7½, 3¾, 1⅞ ips with proportional response. Direct or FM recording. All-transistorized. ½" or 1" tape, 10½" reels.
FR-600: 300 cps to 500 kc ±3 db at 120 ips; 60, 30, 15, 7½, 3¾, 1⅞ ips with proportional response. Direct, PDM or FM recording by plug-in modules. ½" or 1" tape, 10½" or 14" reels.

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NEW PRODUCTS

filled **visual indicators** and cold cathode **trigger tubes** now available. . . . (316) High resolution never before obtained in an **electrostatic printing tube** is available in the Printapix B3C2 CRT now being sold by the **Electron Tube Div., Litton Industries,** San Carlos, Calif. . . . (317) The precision **X-Y recorder** Model 2DR available from **F. L. Moseley Co.,** Pasadena, Calif., draws Cartesian coordinate curves automatically from two related dc sources, along with other operational modes.

Circle No. 315, 316, or 317 on reply card

RESEARCH, TEST, & DEVELOPMENT

CALIBRATES FLOWMETERS

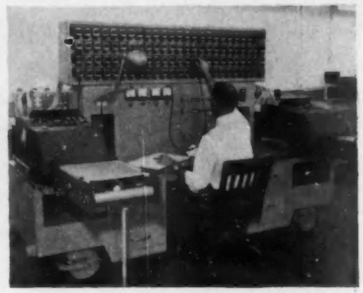
A newly announced flow rate comparator has been developed to laboratory standard quality to compare, calibrate, and check accuracy of liquid flowmeters. Orifice, rotameter, and turbine types can be tested. Flow rates of 0-800 lb per hr can be accommodated. Flowmeters can be tested without removing them from their installation. Comparator's operation is based on dynamic weighing principle: it electronically times the flow of a known weight of liquid. External electronic counter is needed for readout. Accuracy is to within ± 0.025 percent; sensitivity is to 0.0215 percent.—Simmonds Precision Products, Inc., Tarrytown, N. Y.

Circle No. 318 on reply card

VIBRATION METER

This double integrating vibration meter provides standardized output signals of displacement, velocity, and acceleration from any piezoelectric accelerometer, making it useful in calibrating such devices, as well as velocity pickups. A novel sensitivity dial allows adjusting accelerometer sensitivity to give output of 1 volt per in. displacement and 1 volt per g acceleration. Velocity signal is standardized at 96.4 mv (rms per in. per sec).—Upholtz-Dickie Corp., Hamden, Conn.

Circle No. 319 on reply card



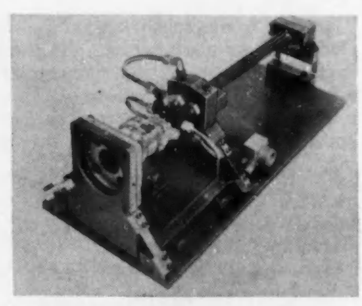
ISOLATES INTERFERENCE

An old problem in missile testing, electromagnetic interference, can be isolated in a new checkout console called the EMI Test Console 101. It is an integrated unit to detect, measure, and analyze EMI in complex missile and aircraft electronic circuits. In one project the manufacturer used the console on tests of its own missile production and saved a total of $18,650 per missile in direct and indirect cost.

Characteristics:

Frequency range: 0 to 400 Mc (extendable with auxiliary equipment)
Linearity: within 1 percent
Stability: within 2 percent over 90 days
Power requirements: 7 kw, 60 cycles, 440 volts standard
Active data channels: 100
—Norair Div., Northrop Corp., Hawthorne, Calif.

Circle No. 320 on reply card



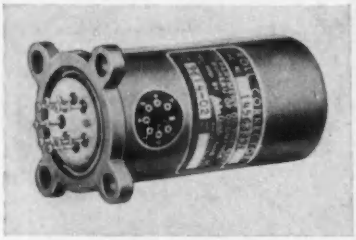
TORQUE TESTER

The torque table shown above is designed for measuring the torque characteristics of hydraulic pumps and motors in the range from 50 oz-

in. to thousands of pound-inches. No limitation is made by the table on speed of rotation or friction since no bearings, slip rings, brushes, or other friction sources are used. Basically the tester is a reaction dynamometer which senses torque by means of special flexures to which bonded strain gages are attached. Price $2,100.—Lebow Associates, Inc., Oak Park, Mich.

Circle No. 321 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



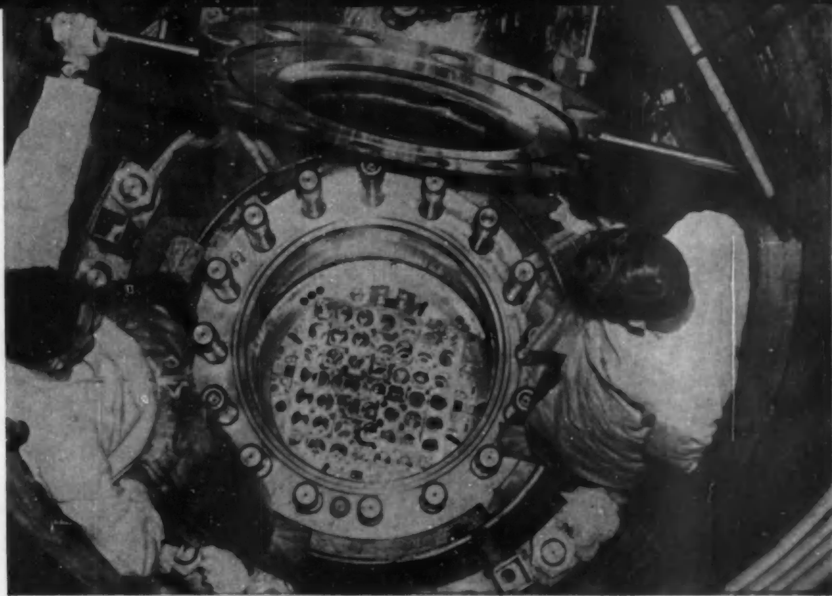
RETAINS POSITION

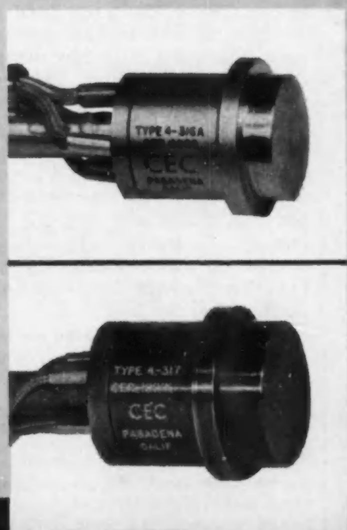
This unique synchro-receiver combines an integral brake in a MIL unit to lock in a received position; the synchro can then act as a transmitter. One possible application: when a missile is fired from a nonstable platform, the missile's relative position at firing is retained by the receiver and transmitted to correct firing position. Synchro is 26-volt, 400-cycle with 1.5-deg error; brake solenoid operates on 35 or 115 vdc. Dimensions are 2$\frac{3}{16}$ x 1$\frac{1}{16}$ in. diam; weight is 4½ oz.—John Oster Manufacturing Co., Avionic Div., Racine, Wis.

Circle No. 322 on reply card

LOW COST IR CELL

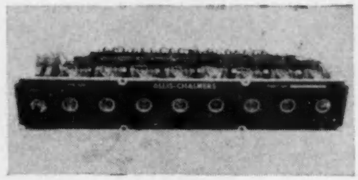
Now available in quantity is a low cost general purpose lead sulfide detector sensitive to visible and intermediate infrared radiation in a range of 0.7-2.7 microns. The cell, designed for industrial applications, has a mean time





constant of 375 microsec and a dark resistance range from 500 kilohms to 1.5 megohms. Price in dual prong plastic housing: $6.15 each in quantities of 12.–Tupper Trent Co., Inc., Chelsea, Mass.

Circle No. 323 on reply card



MILL MONITOR

Reliability and versatility in the operation of complicated mill control systems is offered by this memory-type fault detector. The device monitors the circuit or contact and indicates any malfunction so that troubleshooting is simple and direct. The unit is arranged so that any change in state in the monitored circuit beyond a time delay interval will trigger a controlled rectifier and turn on a high intensity light. Modules of eight circuits are packaged for mounting on control boards.—Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

Circle No. 324 on reply card

SENSES MAGNETICALLY

A position transducer using noncontact magnetic heads has been developed for machine tool automation systems. Reported to reduce wear, the transducer senses shaft rotation and produces digital pulses which measure linear motion. In typical applications the unit detects 0.0001-in. increments at position speeds up to 120 in. per min or 0.001-in. increments at 200 in. per min. Small size and low torque load are also featured. Price (without electronics): $295.–Rheem Electronics Div., Rheem Mfg. Co., Los Angeles, Calif.

Circle No. 325 on reply card

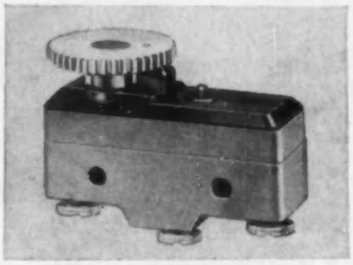
SENSITIVE LEVEL SENSOR

So sensitive is this transistorized level control that even distilled or de-ionized water will complete the 15-microamp circuit through the probes. Features include choice of single point or differential level control, sensitivity adjustment for liquids of various con-

ductivites, and thermistor compensation to cancel effects of changing ambient temperatures. The weather-tight unit actuates an spdt relay that handles 15-amp loads. Price without probes is $70; probes can be shop fabricated or ordered from the manufacturer.—Precision Thermometer & Instrument Co., Philadelphia, Pa.

Circle No. 326 on reply card

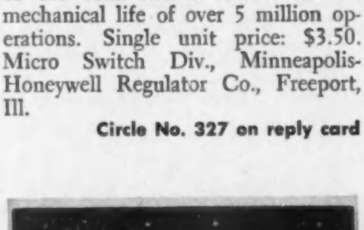
CONTROLLERS, SWITCHES & RELAYS



TRAVEL'S ADJUSTABLE

Simply by turning a knurled wheel on the top of this miniature switch, travel can be varied from 0.0025 to 0.007 in. This changes operating force from 12 to 32 oz and differential force from 2 to 15 oz. Release force, however, remains 10 oz regardless of setting. Designated 10BS210, the switch is rated at 20 amps at 120, 250, or 460 volts and is said to have a mechanical life of over 5 million operations. Single unit price: $3.50. Micro Switch Div., Minneapolis-Honeywell Regulator Co., Freeport, Ill.

Circle No. 327 on reply card

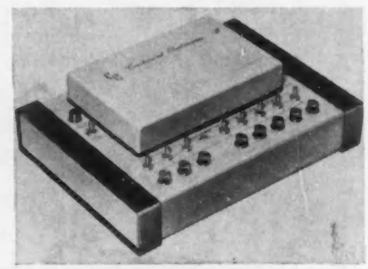


10-POINT CONTROLLER

Accurate automatic two-position control for up to 10 processes is provided by a new multipoint electronic temperature controller. The instrument

also can be used as a single point controller, a five-point, three-position controller, and a manual balance controller. Any points not used for control of a multiple temperature process can monitor other processes. The device combines a sensitive null-balance potentiometer measuring circuit with an electronic control system. It is adaptable to any installation requiring on-off control. Accuracy is to within ±0.5 percent of range.—Thermo Electric Co., Inc., Saddle Brook, N. J.

Circle No. 328 on reply card



PORTABLE CENTER

A portable control center, which can turn on or off up to eight separate switches at any time interval from 30 millisec to 2 years, can be set up quickly and changed or modified in only a few minutes. Unit is controlled by eight-channel punched tape for automatic, semiautomatic, or manual programming. Each channel incorporates an spdt latching relay controlled by the tape. A neon light indicates the state of each channel, and a control switch allows manual control. Price: $895.—Crestmont Electronics Div. of Crestmont Consolidated Corp., Burbank, Calif.

Circle No. 329 on reply card

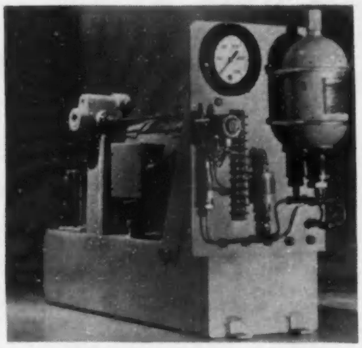
POWER SUPPLIES

TRANSIENT FREE

This new regulated dc power supply eliminates transistor-ruining transients and is excellent for testing of transistor loads since it uses a dynamic regulation circuit with instantaneously reacting transistors. Static regulation is by magnetic amplifiers. Output is 0-36 volts at 5 amp. Dynamic line regulation is within 15 mv, and maximum ripple is within 2 mv rms. The supply,

designated MTRO36-5A, is mounted in a 5¼-in. rack and is short-circuit-proof, fuseless, has no turn on transient, and has adjustable automatic current limiting.—Perkin Electronics Corp., El Segundo, Calif.

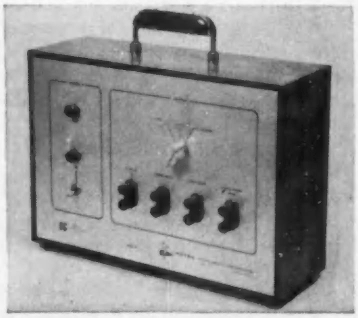
Circle No. 330 on reply card



HIGH PRESSURE, LOW FLOW

According to the manufacturer, this hydraulic power supply meets a requirement not yet met by other commercially available units: a high pressure, low flow supply. Pressures to 2,000 psi are delivered at only 0.5 gpm. The high pressure permits using smaller piston sizes, reducing the overall size of the control system. A nitrogen accumulator is used to remove pressure drops and surges. High reliability switch regulates system pressure to within ±50 psi. Pump drive can be 220 or 440-volt, three-phase, 60-cycle. Prices start at $800.—System Analysis, Inc., Endicott, N. Y.

Circle No. 331 on reply card



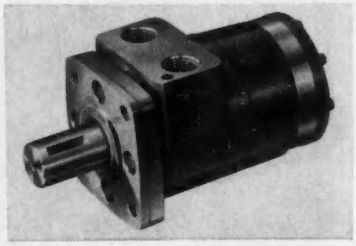
ABSOLUTE SOURCE

Absolute voltage accuracy to within 0.0075 percent and current accuracy to within 0.025 percent makes this dc supply suitable for use as a portable secondary standard. Stability for voltage outputs is to within 0.003 percent; current, to within 0.005 percent. Voltage outputs are 10.000 vdc at 0-20 ma and 1.000 and 1.0185 vdc for potentiometric use. Current outputs are

7.5 and 10 ma at 0-16 vdc. Input required is 105-125 volts, 47-440 cps, 30 watts. Price: $1,075.–Rotek Instrument Corp., Cambridge, Mass.

Circle No. 332 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



INSTANTLY REVERSIBLE

These hydraulic motors feature low speed and high torque. Instantly reversible, they develop a maximum of 3,300 lb-in. torque at 1,500 psi with intermittent pressures up to 2,000 psi. Top speed of the smallest power element is 800 rpm with a maximum torque of 500 lb-in. at 1,500 psi. Length is 6.5 in. and diameter is about 3.25 in. There are four types of mounting, three port sizes, and six power elements available. All models are priced below $100.–Char-Lynn Co., Minneapolis, Minn.

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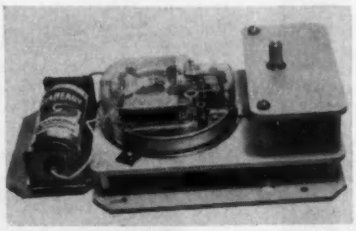

TIMED MOTORS

High accuracy and long life are the features of this series of chronometrically governed dc motors. The 1.5-volt motor operates for more than two years on a standard flashlight cell. Constant speed of 150 rpm is maintained by a balance wheel-hairspring

mechanism, with an accuracy to within ±10 sec in 24 hr—even with an input voltage range of 0.9-1.8 volts. Just 1¾x2½x½ in. and weighing 3 oz, the motors can be supplied with windings for voltages from 0.5 to 12 vdc. Possible applications include operating contacts, cams, and actuators, where loads are larger and vary over a greater range than escapement types can handle.—The A. W. Haydon Co., Waterbury, Conn.

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12-POSITION VALVE

Suitable for automatic gas sampling and as an automatic sample feed to gas chromatographs or mass spectrographs, this 12-position automatic valve has 12 separate intake ports connected to a common vacuum chamber. Each valve is sealed by a spring loaded ball valve except when the port is open for sampling. Cam controls port opening by moving a rod to unseat the ball; the cam is activated by Geneva motion coupled to shaded pole motor. A 3-sec electrical pulse moves valve from one position to another; 10 sec are needed to detent to new position. Price: $134.—Gelman Instrument Co., Chelsea, Mich.

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PLUS . . .

(336) Subfractional **four shaded pole gearmotor** is available in 1/30, 1/60, and 1/100 hp models in nine speeds (1-200 rpm) from **von Weise Gear Co.,** St. Louis, Mo. . . . (337) **Marotta Valve Corp.,** Boonton, N. J., has placed on the market a three-way, two-position NC or NO **magnetic or manually operated valve** in a symmetrical body design that allows manifolding in various positions.

Circle No. 336 or 337 on reply card

COMPONENT PARTS

DIGITAL COUNTER

Up to 150,000 cps (or 1 million cps on special order) can be counted on this miniature solid state digital ring

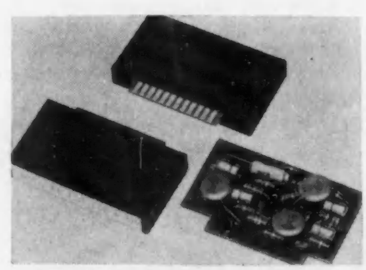
counter. It is guaranteed not to miss a count in forward, backward, or intermittent switching. For coupling the trigger signals to the counting circuit, the design employs dc logic. This way the counter is made insensitive to conducted line noise, radiated noise, line voltage variations, and other variables. Standard models provide one output pulse for each count of 10 input pulses. Operating temperature range is −55 to +125 deg C. Units may be cascaded without external circuits.—Tempo Instrument, Inc., Hicksville, N. Y.

Circle No. 338 on reply card

OVERRUNNING COUPLINGS

A precision steel spring is the sensing element in these one-way couplings. In the driving direction the spring tightens, the coupling engages with little backlash and drives without slip. In the overrunning direction the spring unwinds permitting the hubs to slip. Stock shaft sizes accepted range from $\frac{1}{8}$ to 1 in., with special units available on order. All units come with sintered bronze swivel bearing, plastic locking set screws, and aluminum dust cover. Price for $\frac{1}{8}$-in. size: \$3.—International Mechanisms, Fairport, N. Y.

Circle No. 339 on reply card

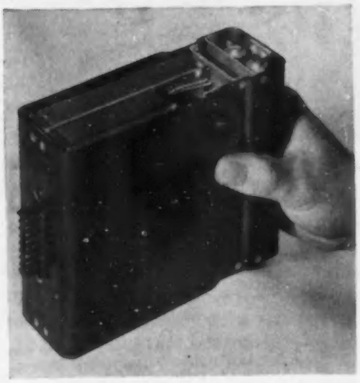


LOW COST MODULES

Low cost plug-in building blocks for digital computing applications are now available in a convenient silicone rubber encapsulated configuration. In-

cluded are flip-flop, multivibrator, and univibrator elements in any combination. Each $\frac{1}{2}$x2$\frac{3}{4}$x3$\frac{1}{8}$ in. package contains two elements in any combination and weighs 2 oz. Standard operating voltage is 18 vdc; other units are available for 6 to 20-vdc operation. Frequency response of flip-flops is to above 20 kc, multivibrators are available with any frequency from 250 cps to 20 kcps, and univibrators may have any pulse duration from 4 microsec to 4 millisec. Price is sample quantities: $14.—Marketing Computers, Inc., Florissant, Mo.

Circle No. 340 on reply card



IMPORTED AMPLIFIER

Licensed from the German firm Güttinger for manufacture for the U.S. market, this transistorized operational amplifier features drift of only 10 microvolts in 24 hours. Short-circuit-proof, the device operates on ±60 volts and has a loop gain of better than 20 million. Output swing is ±50 volts; input impedance is 1 megohm; and load capability is 25 ma at ±50 volts and 75 ma at 0 volts. Price: $375. Boonshaft and Fuchs, Inc., Hatboro, Pa.

Circle No. 341 on reply card

ACCESSORIES

SIMULATES 650

Three versions of a system designed to simulate the IBM 650 punched card computer on the RCA 501 have been made available. The three versions allow users of 501's with two, three, or four modules of available core memory to use the many 650 programs available. A two-module 501 will be able to simulate a 2,000-word 650 with punched card input and output. Users of a three-module 501 will also be able to simulate 650

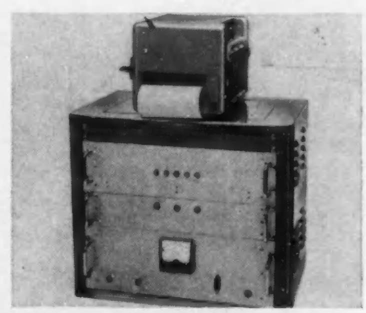
index registers. A user of a four-module computer will be able to simulate a 650 with 4,000 words of memory and index registers.—Applied Data Research, Inc., Princeton, N.J.

Circle No. 342 on reply card

VERIFIES DIGITS

About the size of a portable radio, this check digit verifier is designed to operate cable-connected to the manufacturer's accounting machines. When an entry is made, the verifier performs a computation on the account number before it is entered on tape. If an error is detected, the computer stops. With this transistorized unit, the designers assert, the mathematical probability of an incorrect entry is insignificant. Price: $1,350. — Burroughs Corp., Detroit, Mich.

Circle No. 343 on reply card



INPUT CALIBRATION

For accurate recording of dynamic temperatures from thermocouple inputs, it is necessary to calibrate out error due to loss in input cabling. A temperature calibrator, operating on its own power supply, has been designed to do this with simultaneous or sequential four-step calibration, individual channel span and damping resistors, and individual calibration level resistors.—B&F Instruments Inc., Philadelphia, Pa.

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  Special report highlights basic transistor switching techniques, available systems and components, design and application hints, and many case studies across industry.
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  Altered conventional pneumatic controller gives benefits of sampling control.
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318	329	340	351	362	373	384	395	406	417	428	439	450	461	472
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473

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ADVERTISEMENTS *Mail Before May 1, 1961*

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5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
9	23	37	51	65	79	93	107	121	135	149	163	177	191	205	219	233	247	261	275	289	303
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314	325	336	347	358	369	380	391	402	413	424	435	446	457	468
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469
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506—Adaptive Control Systems, 50 cents
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484—How to Use Phase-Plane Techniques, 50 cents
483—Economics in Control, 50 cents
482—Static Switching Devices, 50 cents
480—Applying Control Timers, 50 cents
478—Servo Modulators, 65 cents
477—Basic Data on Process Control Systems, 50 cents
476—Three Ways to Simulate Dead Time, 15 cents

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(Continued from page 165)

9. ACCESSORIES AND MATERIALS

Advertisements

New Products

Bulletins and Catalogs

CONTROL BITS

Production monitoring of 200 winding machines is being performed at Owens-Corning Fiberglas Corp.'s Aiken, S. C., plant by a new production control system built by Information Systems, Inc. Called the ISI Production Data System, it contains the basic circuitry of ISI's incremental control computer and the disc magnetic memory designed by Genesys Corp. before its merger with Information Systems. Unit scans two points on each machine every 11 sec.

•

First three-spindle, tape-controlled Keller milling machine has been installed by Boeing Airplane Co.'s Wichita (Kansas) Div. to make parts for the B-52 bomber. Bendix numerical control run Pratt & Whitney unit.

•

Missile detection studies are underway at Convair (San Diego) Div. of General Dynamics Corp. Convair is using gold-doped germanium and indium antimonide infrared dectectors, with a response time of one-millionth of a second to make measurements of gases superheated by ultrasonic shock waves to temperatures of 5,000 to 21,000 deg. F.

BULLETINS AND CATALOGS

(400) MICROWAVE GUIDE. Hewlett-Packard Co. Application Note No. 46, 100 pp. Entitled "Introduction to Microwave Measurements", profusely illustrated book is useful as an introduction to the specialized field it covers. Included are background information on microwaves, discussion of transmission theory, and description of basic measuring equipment. Appendix includes glossary of microwave terms and equipment data sheets.

(401) RESPONSE CALCULATOR. Hagan Chemicals & Controls, Inc. Pocket-size slide rule type of calculator eliminates need for regular slide rule computation or complex chart references when plotting frequency response curves.

(402) CONVERSION CHART. Rosemount Engineering Co. Bulletin 10605 (Rev), 2 pp. Handy chart permits rapid, accurate conversion from any scale—Kelvin, Rankine, centigrade, or Fahrenheit—to any other scale. Conversion range is from absolute zero to 16,000 deg C.

(403) STANDBY POWER SUPPLIES. Consolidated Diesel Electric Corp. Bulletin P-2, 8 pp. Describes a line of uninterrupted power supplies that provide absolutely continuous power in case of normal-power failures. Unique design does not require an engine to start up and come up to speed before assuming electrical load.

(404) RESIN MOLDING COMPOUNDS. Food Machinery and Chemical Corp. Booklet, 26 pp. Describes properties, uses, and molding requirements of compounds based on Dapon diallyl phthalate resins. Includes complete tables to guide molders, designers, and specifiers on the capabilities and application techniques of these materials.

(405) BLAST FURNACE CONTROL. Hagan Chemicals & Controls, Inc. Bulletin MSA-190, 24 pp. Attractively laid out with charts, diagrams, and photographs, bulletin describes application of automatic control systems to eleven areas of blast furnace operation. Includes description of application of data processing equipment for both operation and research.

(406) PNEUMATIC CONTROLLERS. Black, Sivalls & Bryson. Bulletin 72-117, 28 pp. Discusses economic application and design of pneumatic control systems; uses cartoon technique to show how a controller is built. Descriptions and photographs of components in pneumatics line are included.

(407) CONTROLLED POWER. Hamilton Standard Div., United Aircraft Corp. Booklet, 16 pp. Static power conversion guide explains new field of controlled electrical power. Advantages of this type of equipment are outlined, and useful comparisons are given between static and rotating electrical devices.

(408) RESISTOR STUDY. International Resistance Co., Burlington Div. Handbook, 28 pp. Presents the results of a project to study performance and reliability of molded deposited carbon resistors. Includes data on tests of more than 37,000 units, presented graphically in more than 20 charts and diagrams. Variables like

temperature cycle, short time overload, terminal strength, dry and wet dielectric strength, moisture resistance, and load life are included.

(409) MACHINE CONTROL TRANSFORMERS. Acme Electric Corp. Catalog 141-BO1, 4 pp. Describes functions of transformers for machine tool control and serves as a guide in determining proper transformer to be used in any application.

(410) EDP SURVEY. Walter R. Oreamuno & Co., Inc. Chart. Updated version of a spring 1960 survey of domestic electronic data processing equipment. Includes seven new computers and many specification changes. Also given is a new data processing bibliography.

(411) DIGITAL RECORDING. Minneapolis-Honeywell Regulator Co., Industrial Systems Div. Brochure, 20 pp. Describes applications for digital tape recording techniques including communications, filing, media conversion, acquisition and reduction, and high and low speed sampling. Functional and block diagrams are included along with photographs and descriptions of the equipment.

(412) RECTIFIER APPLICATION GUIDES. General Electric Co., Electronic Components Div. Charts. These two wall charts are all that is needed to select the best rectifier for any circuit. The first, "Characteristics of Common Rectifier Circuits", is used to find the voltage and current parameters to be used in the circuit. These are then applied in the second, "Rectifier Selection Chart".

(413) FLUID FILTRATION. Screen Products, Inc. Catalog, 36 pp. Serves as a design engineering manual for the application of all-metal filter assemblies in the filtration of lube oils, hydraulic fluids, coolants, and other liquids. Complete data and formulas needed to determine filter requirements for most systems are given along with performance characteristics of currently used filter assemblies.

(414) IR PHOTOELECTRIC CONTROL. Cramer Controls Corp., Electronics Div. Bulletin, 8 pp. Illustrated publication describes operation of Infrabeam, an infrared photoelectric controller which functions by reflected or interrupted beam, long range, and under high general light conditions. Included are illustrations of installations involving materials handling, counting, inspection, and control. Detailed specifications are given of equipment and accessories.

(415) POWER CENTERS. General Electric Co. Bulletin GEA-7080, 12 pp. Describes the Cabinetrol industrial power centers which are engineered and custom-built to customer specifications. Explains advantages of individualized panels.

(416) CERTIFIED RECTIFIERS. Semiconductor Div. of Syntron Co. Condensed catalog 100, 8 pp. Attractive color-illustrated catalog features cutaway drawings of silicon and selenium diodes, stacks, and cartridge rectifiers. Full list of over 350

JEDEC types along with complete electrical and mechanical specifications are included. Company's unique certification and guarantee policy is spelled out.

(417) 8 AND 11 SERVOMOTORS. Helipot Div., Beckman Instruments, Inc. Catalog, 24 pp. New models and updated specs on Size 8 and Size 11 servomotors are included in this new two-color catalog. Complete electrical and mechanical specifications, outline drawings, and torque-speed curves are given for the lines which include servomotors, velocity-damp servomotors, inertia-damp servomotors, and servomotor-generators. Also included is two-page discussion of damping theory.

(418) 600-CHANNEL MULTIPLEXING SYSTEM. Lynch Communication Systems, Inc. Brochure, 12 pp. Describes the B910 transistorized multiplexing channeling equipment capable of channeling as many as 600 conversations or other types of information. Complete page of specifications is included.

(419) OPTICAL MASER ARTICLE. Bell Telephone Laboratories, Inc. Booklet, 8 pp. Consists of a reprint of a *Bell Laboratories Record* article describing the theory and design of the recently announced solid-state optical maser. Several photographs including full-color picture of an operating maser complement the text.

(420) NUMERICAL CONTROL SYSTEM. General Electric Co. Bulletin GEA-7209, 4 pp. Describes latest version of company's numerical control equipment, the Mark Century, capable of performing positioning and contouring from standard punched tape programs. Included in the booklet are descriptions of point-to-point positioning and continuous path functions. Computerless contouring is also summarized.

(421) INSIDE POWER STORY. Valor Instruments, Inc. Brochure, 18 pp. Explains troubles originating in poorly regulated power supplies. Entitled "The Inside Story of the New Plug-In Power Supply Modules", booklet gives detailed account of the design achievements of these new power sources.

(422) CHARTS AND INKS. Minneapolis-Honeywell Regulator Co., Industrial Div. Catalog G-100-6, 24 pp. Along with a complete description of how charts and inks are made, this booklet gives partial lists of the most commonly used ElectroniK strip and circular charts, pneumatic and electric Tel-O-Set charts, and recording inks.

(423) LIQUID HYDROMETER. The Liquidometer Corp. Bulletin, 16 pp. Entitled "Liquid Measurement in Pounds", revised edition describes applications of these electric hydrometers. Applications included are those which require direct measurement of liquid density or true weight tank contents indication.

(424) CIRCUIT BOARD DESIGN MANUAL. Dytronics, Inc., Sub. of Taylor Fibre Co. Bulletin No. D1, 12 pp. First section compares features of die stamped circuits (in which die cut conductor patterns are bonded to base material) and those of etched copper-clad laminated plastics. Second section gives hints for circuit designs using the die stamped circuit components. Last page gives defi-

nitions for common terms used in printed circuit design.

(425) APPLICATION NOTE. Computer Systems, Inc. Form 80-105-008, 9 pp. Report describes application of the Dystac dynamic storage analog computer to determination of complex chemical equilibrium conditions and composition. Instrumentation required is listed, and diagrams show equipment interconnection for reactions, heat balance, and equilibrium composition. Mathematical derivations and equations are indicated, and installation and operation of the equipment are described.

(426) SEMICONDUCTOR APPLICATION. Semiconductor Div., Hoffman Electronics Corp. Application News, September-October, 16 pp. Illustrated articles are entitled: "Voltage Regulator Diode Surge Ratings", "The Silicon Uni-Tunnel Diode", and "Solar Cells for Voice Transmission".

(427) VOLTAGE COMPARATORS. Non-Linear Systems, Inc. Bulletin 50-1, 6 pp. Two-color bulletin describes the company's Model 50 voltage comparator and the Model 51 voltage comparison amplifier and discusses application of each. Problem and solution section shows how to design complete go/no-go testing systems and how to select the correct voltage comparator and comparison amplifier for many other applications.

(428) SNAP-ACTION SWITCHES. Licon Div. Illinois Tool Works. 1961 Catalog, 32 pp. Features a unique four-page technical discussion of switches and switch terminology, as well as complete and concise product descriptions. All of the company's basic sensitive switches, miniature and 10-amp rated subminiature units, heavy duty models, enclosed limit switches, and a complete line of auxiliary actuators are included.

(429) RECORDING OSCILLOGRAPH. Electro Mechanical Instrument Div., Consolidated Electrodynamics Corp. Bulletin 5124, 4 pp. Contains photos and specifications describing the operation of a new, low-cost, portable recording oscillograph. Discusses interesting design features and lists optional accessories.

(430) PRESET TOTALIZER. Potter Aeronautical Corp. Bulletin No. D-222, 4 pp. Describes an automatic predetermined counter that provides pushbutton control of fluid measuring, batching, mixing, or blending. Illustrates a typical small plant installation in which the weighing tanks, batch tanks, and associated plumbing have been eliminated.

(431) POWER CONVERSION. Power Sources, Inc. Short Form Catalog 60A, 8 pp. Offers details on a complete line of solid state power supplies and power conversion devices. Brochure includes pictures and text describing the company's exclusive Sineverter line of solid state sine wave inverters, low-voltage transistor regulated power supplies, high-voltage transistorized supplies, and five solid state power converters for special applications.

(Continued from page 50)

for specific industries.

In selling Systemation, Allis-Chalmers uses what one A-C man describes as a "rifle-shooting" technique. Not only is one special industry picked to concentrate on, but special customers within those industries—the customers who most need sophisticated electronic control or who are thinking about it—are chosen.

Teams were formed, combining the elements of process knowledge, basic equipment, and electronics. In power generation, the CSC specialist is Wilson; in processing, Edwards; and in metalworking, Felberg.

A typical team might consist of a controls man, a power man, a CSC man, and an engineer with a special process knowledge. They choose a particular project and work very closely with a potential customer. If a contract is obtained, one of the team's members drops out to head the project and is replaced by another man.

In the Gulf States project, CSC sent a three-man group to Lake Charles, La., site of the power station, and worked with Allis-Chalmers engineers on system equations to determine what sort of signals would be needed and the types of outputs to be used for automatic startup and shutdown of the two A-C turbines.

A-C has a sharp eye out for Systemation possibilities in the dry process industries—cement, lime, ore, chemicals, etc. There is very little advanced electronics system application in this area, and A-C is a leading manufacturer of the basic equipment. For instance, more than 50 percent of the cement made in the U.S. is made in Allis-Chalmers kilns.

In the two other industries that A-C is concentrating its efforts on—metal rolling and power generation—the company has already had experience in tying in advanced electronics systems for optimizing purposes. Data logging, card programming, and partial computer control are expected to play an increasing role in automatic screwdown, gage control, and tension measurement—in steel mills where A-C gets contracts—and in automatic startup, automatic loading, and optimizing of power generating stations.

Other industries, where A-C already has basic knowledge, and which hold possibilities for A-C electronics systems, include paper, textiles, rubber, petroleum, and food processing. Some of these are now under study.

In its sales efforts A-C stresses the "prudent investment" theme of its

definition. "We do not want to sell a customer a million dollar computer if all he needs is data logging equipment," says an executive.

• **Free choice**—Engineers have the entire line of commercially available computers to choose from, since CSC no longer makes them, and can make a selection on the basis of what best fits individual requirements. As for the other components, CSC still uses a lot of CEC equipment, but many of its systems now have little or no equipment made by CEC.

"If there is an application for CEC equipment, we use it, but we are not restricted to it," says a CSC engineer. "We're not trying to sell a device we've built for a particular job, and when we start out on a job, we have no specific equipment in mind – only methods."

As Allis-Chalmers expands in electronics systems applications, it is likely that the company will make at least some of the sensing instruments it has been buying. A-C's Controls Dept. already is a big supplier of activating controls. "We definitely think we can make pressure transducers at a profit," says Donald B. Scott, head of the Controls Dept. The company is also studying the possibility of profit potential in making other instruments.

—Stewart W. Ramsey
McGraw-Hill News

LA's Biggest is Now Electronics

LOS ANGELES—

The shift in product lines and company leaders and organization that has turned many aircraft companies into electronic firms—not to mention the host of firms started in the postwar years in this field—has finally turned the tide in Los Angeles, long the center of the aircraft industry. Electronics industry employment figures here will soon forge ahead of totals for the aircraft-missile industry to mark an historic change in the area's labor market.

For 20 years aircraft building has been the major industry of Los Angeles, but in recent years it has steadily lost ground to the burgeoning electronics business. According to a Security First National Bank report issued here, electronics employment currently stands at 126,000 in the Los Angeles-Long Beach area. But it will top aircraft employment, now at 143,000, by the end of this year.

More Computer Control: IBM and Du Pont Study A Tricky New Process

NEW YORK—

How do you control a new process that has some unpredictable, uncontrolled variables and whose disturbance patterns are unpredictable? Most oil and chemical companies shy away from putting such processes into production. However, a computer study announced last month may open a whole new approach to these processes.

After 18 months of secret study, International Business Machines Corporation and E. I. du Pont de Nemours Co, have announced a joint project to apply a computer to control an unusually large pilot plant built to produce acrylonitrile by a new catalytic process. Conventional control and instrumentation was not satisfactory for the new Du Pont process because the efficiency of the catalyst is so sensitive to operating conditions and the acrylonitrile reaction itself is a time-varying, nonlinear system.

Research studies have shown that a significant improvement in the process is possible by adjustments which can be accomplished only through dynamic computer control, so much improvement that Du Pont feels computer control is the only way the process can be commercially feasible. What the IBM-Du Pont team says it can accomplish is truly dynamic control in which the setpoints of controllers change continuously as the computer computes and recomputes settings.

• **Dynamic optimums**—The problem, says IBM researcher Dr. Eugene Shapiro, is one of dynamic optimization. In the new acrylonitrile process the computer will attempt to find an optimum and plot the most direct route to the optimum in minimum time—subject to constraints which are also dynamic.

Exactly how to program the computer to do this has not yet been resolved. One approach that looks promising is the method of dynamic programming as propounded by Rand Corp.'s Richard Bellman. Dynamic programming, a computer algorithm, is a prescription for solving a maximizing equation. In addition, the technique defines the optimal solution, which becomes a goal to strive for. And it enables the programmer to state the problem in a form which is related to how to use the computer.

One question to be answered is whether the computer will have the arithmetic capability to solve by dynamic programming the acrylonitrile reaction and determine setpoints fast enough with respect to the process time, constantly ranging from five

WHAT'S NEW

to 20 minutes.

If the team successfully applies dynamic programming, the installation will be the first industrial application of this theoretical technique, which so far has been talked of only in terms of promise.

• **Up to 20 inputs**—Another aspect of the problem not yet made final is how many input variables the computer will receive and how many controller settings it will calculate. A Du Pont engineer said the machine would probably receive between 10 and 20 measurements and would control between 10 and 20 valves. Considerable analysis instrumentation will be connected on line with the computer to supply the input information. Definitely included to date are a mass spectrometer and a chromatograph.

Present plans call for using IBM's new process control computer, the not yet announced or available IBM 1720. One feature it probably will have: almost three times the memory of the computer used in the IBM-Standard of Indiana computer control experiment (CtE, Nov. '59, p. 40).

Bullard Takes Court Action In Control Patent Test

The Bullard Co., Bridgeport, Conn., machine tool builder, has taken its first court action to enforce its claims of basic patent rights in numerical control. As first reported in CtE (July '60, p. 17 and Sept. '60, p. 54), Bullard asserts that its patents involving Man-Au-Trol dating from 1944 are basic to modern numerical control. Last month it filed suit against General Electric Co. charging infringement of the patents.

Bullard's patent plan up to now has involved negotiations with some 20 U. S. and foreign control and machine builders. Commenting on the court action against GE, President E. P. Bullard said, "This step was taken only after correspondence and amicable discussion with General Electric regarding the matter. The relations between General Electric Co. and The Bullard Co. have always been most friendly, and it was with great reluctance that we authorized our patent counsel to file a bill of complaint on this infringement." Bullard explained that the action did not affect his company's offer to license GE under the patents at this time.

The bill of complaint, filed in the District Court at Charlottesville, Va., requested: 1) preliminary and final in-

WHAT'S NEW

junctions against GE's alleged patent infringement, 2) damage award with threefold increase because of the claimed wilful and wanton nature of infringement along with an accounting to determine the damages, and 3) assessment of costs and attorney's fees against GE plus any other relief that might be required.

TI Forms Group to Push Industrial Controls

The Apparatus Div. of Texas Instruments, Inc. has formed a special products department to speed the development of industrial control systems. The division of the Dallas firm has depended in the past on the military for 95 percent of its sales.

The aim of the new group is to put together industrial systems from components and products turned out by TI's various divisions. Currently under development is a burner control system for a Dallas Power & Light Co. power plant which will place the plant's boilers under automatic control. TI describes the system as a new application of solid state devices.

W. R. Bailey is manager of the new department. He notes that machine tool numerical control will be a prime target for his group's efforts.

Burtek Acquires Concord From Giddings & Lewis

Giddings & Lewis Machine Tool Co. has sold its interest in Concord Control, Inc. of Boston to Burtek, Inc. Concord specializes in digital computing devices, data handling, and control systems engineering.

Burtek, of Tulsa, Okla., claims to be the world's largest independent producer of technical training devices. It is the second major acquisition in the past year for Burtek. Last January the company purchased the electronics division of the Divco-Wayne Corp.

Concord has been a supplier of numerical control equipment to G & L. Under the terms of the present arrangement, Concord will continue to supply G & L on a subcontract basis; but it will also develop new product lines for Burtek.

News of Other Firms In the Control Field

Susquehanna Sciences, Inc., has been formed in Pasadena, Calif., by The Susquehanna Corp. of Chicago.

The new division includes three companies acquired by Susquehanna in the past year: Computer Engineering Associates, Birdsell Products, and Thor Electronics. J. Patrick Lannan, president of the parent firm, is hoping for $20-30 million sales for the new division with five years.

General Electric Co.'s Computer Dept. has announced plans to build an Advanced Computer Development and Research Laboratory in Sunnyvale, Calif. The $1.5 million lab will be headed by Dr. C. F. Spitzer.

Perkin-Elmer Corp. of Norwalk, Conn., has signed an agreement with Hitachi Ltd. of Tokyo to establish a joint company, Hitachi Perkin-Elmer Ltd. in Japan. Subject to validation by the Japanese government, the agreement calls for the joint venture outfit to coordinate the development, manufacture, and sales of instruments throughout the free world.

Fisher Governor Co., Marshalltown, Iowa, has acquired the E. Herbert Vickery Co. of Oakland, Calif. Vickery manufactures a line of advanced design ball-type valves.

Dynisco, Inc., a Cambridge, Mass., producer of electromechanical transducers and sensitive measuring devices, has been acquired by American Brake Shoe Co. Dynisco will remain in its present location under its current management.

Dorsett Electronic Laboratories, Inc., of Norman, Okla., has acquired all outstanding shares of American Missile Products, Inc. in Lawndale, Calif. The latter firm was the Electronics Div. of the Maytag Co.

Hathaway Instruments, Inc. has purchased the Southwestern Industrial Electronics product line from Dresser Industries of Houston. The line of SIE test instruments will be produced in Hathaway's Denver plant.

Quantatron, Inc. has been organized by Union Texas Natural Gas Corp. of Houston. President of the firm is Robert M. Salter, formerly president of Sigma Corp. and a director of the USAF satellite program at the Rand Corp. Product area of the company will center around advanced physics, microwave electronics, information technology, quantum electronics, and space technology.

Data Sciences, Inc. in Great Neck, N.Y., has been formed by TYCO, Inc. of Boston to offer services in the analysis, design, and installation of information systems.

IMPORTANT MOVES BY KEY PEOPLE

Haanstra New V-P at IBM's General Products Div.

Announcement of the promotion of John W. Haanstra to the post of vice-president of its General Products Div. has been made by International Business Machines Corp. Haanstra had been assistant general manager for new products for the White Plains, N. Y., IBM unit.

Haanstra has been with IBM since 1950, when he joined the company as a technical engineer. In 1952 he was assigned to the San Jose (Calif.) laboratory where he worked on the planning and development of IBM's RAMAC machines.

In his new post Haanstra will be primarily responsible for product and technical development programs in the division.

Barr Now Lear-Romec General Manager

A 21-year employee of Romec, Leroy R. Barr, has been named general manager of the Lear-Romec Div. of Lear, Inc. He assumes the post following the retirement of H. C. Andrus, former vice-president and general manager.

Barr, 42, has been with Romec in Elyria, Ohio, since 1936, except for four years of military service during World War II. He started as a factory apprentice and later became draftsman, project engineer, assistant chief engineer, chief engineer, and assistant general manager.

Dr. Alperin Heads New California Company

Circuit Dyne Corp., a new company formed in Pasadena, Calif., has elected Dr. Morton Alperin chairman of the board. Circuit-Dyne manufactures custom designed subsystems and magnetic components for power generation, distribution, and control.

Dr. Alperin was formerly director and president of Space Systems and Industrial Automation, a subsidiary of Idaho Maryland Industries. He was also director of advanced studies for the Air Force Office of Scientific Research. Project Far Side was carried out under his direct supervision.

Other positions he has held include director of aeronautical sciences for AFOSR, and he has been a consultant to several organizations, commercial and military, including the Office of Naval Research. Dr. Alperin is a graduate of California Institute of Technology with a PhD in aeronautics and mathematics.

Hudes in Engineering Post At Telechrome Manufacturing

Solomon Hudes is the new vice-president in charge of engineering of the Telechrome Manufacturing Corp., Amityville, N. Y. He joins the diversified company from a post as executive vice-president of Schaevitz Engineering.

In his Telechrome position Hudes will coordinate the engineering activities of the firm's divisions and affiliated companies: Hammarlund Automation Div., Telechrome Electronics Div, Hammarlund Manufacturing Co., and Universal Transistor Products, Inc. Hudes will also head Telechrome's central research and development group.

For the past 10 years Hudes has worked on the planning and design of various weapon and missile systems. He also has experience in commercial and industrial control systems.

Other Important Moves

Albert F. Sperry has resigned as chairman of the board of Information Systems, Inc., a subsidiary of Chance Vought, Inc. He intends to enter the field of consulting for user companies concentrating on problems involving complex industrial control.

Jack K. Walker is now with Packard Bell Electronics Corp. as director of planning for its Defense and Industrial Group in Los Angeles. Walker was director of marketing and engineering at GPE Controls, Inc., and director of

marketing at Librascope. He previously held posts with Consolidated Electrodynamics Corp. and Socony Mobil Research Laboratories.

D. L. Nettleton, who participated in the design of the first RCA computer, is now the chief engineer of RCA's Data Processing Div. He had been engineering manager of RCA Data Communications and Customs Projects Dept., part of the EDP Div.

George J. Dickey has become vice-president and assistant general manager and Dr. Nisson A. Finkelstein has been appointed vice-president in charge of research of the Stromberg-Carlson Div. of General Dynamics Corp. in Rochester, N. Y.

Donald E. Garr, formerly manager of engineering operations for GE's Armament and Control Section, has become corporate director of engineering for the Raytheon Co.

J. H. Overholzer has been named executive vice-president of U. S. Systems, Inc., Los Angeles. He was formerly president and founder of Dyna-Matics Corp., a U. S. Systems subsidiary.

Anatol W. Holt is a new member of the staff of Applied Data Research, Inc of Princeton, N.J. Until recently he was employed by Remington Rand Univac where he worked with the late W. J. Turanski on the development of Generalized Programming. For the last two years he developed, at the Moore School of Electrical Engineering of the University of Pennsylvania, Automatic Code Translation for the Signal Corps.

Thomas G. Lanphier, Jr., has become president of Fairbanks, Morse & Co., the largest manufacturing component of Fairbanks Whitney Corp. Lanphier joined Fairbanks Whitney in September as a vice-president of the parent firm and will continue to hold that position. He was vice-president and assistant to the president of Convair Div. of General Dynamics Corp. for almost 10 years.

H. G. Place, who was head of General Precision Equipment Corp. during its 1947–59 acquisition period, has retired as founder chairman of New York firm. During his tenure as president and board chairman, GPE acquired its Kearfott, Link, Graflex, and Shand and Jurs units.

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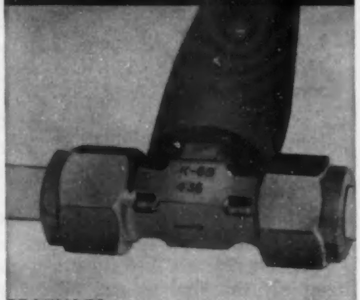
MASS FLOWMETER

measures flow of air and gases electrically



FEATURES

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- **usable from —300°F to +300°F**
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5) **3000-30,000 Std. cc/min.**

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ABSTRACTS

Assuring stability for sampled-data, on-off controls

From "Pulse-Width Relay Control in Sampling Systems", by Winston L. Nelson, Bell telephone Laboratories. Paper No. 60-JAC-4 sponsored by the American Society of Mechanical Engineers for presentation at the Joint Automatic Control Conference, Cambridge, Mass., Sept. 6-9, 1960.

In this paper, one of the most interesting and best presentations at JACC, Dr. Nelson investigates quite rigorously the analysis and design of control systems employing time-sampled inputs and on-off (relay) application of load power to correct output error. In doing so he adds the facility of adjusting the "on" time to proportionally adjust the correction energy so as to make the system asymptotically stable in the large.

In some systems, certain benefits accrue both from using sampled inputs (sometimes a matter of necessity, depending on the inherent nature of the input signal) and from using simple on-off actuation of the load. Systems that exhibit asymptotic stability with continuous control will not, in general, be asymptotically stable when subject to sampling because of the interaction between on-off control and sampling. When the relay control is subject to sampled data, the control inputs are restricted not only in amplitude but also in time. The inputs are restricted to change value only at periodic sampling instants T. To make these systems stable, Dr. Nelson proves the generality of, and employs, these analytical steps:

▶ First, by using phase-space plots, the analysis shows that adjusting the feedback coefficient vector (the control function) rotates the reversal (switching) surface so that all limit cycles other than the $2T$-period limit cycle can be eliminated.

▶ "If the excursions about the equilibrium state resulting from this inherent $2T$-period limit cycle are within the tolerances of accuracy of the specific control problem, then simple relay control in a sampling system may be adequate, provided the feedback-control function which defines the reversal surface in state space is chosen to eliminate the higher-period limit cycles."

▶ When such behavior is not adequate or tolerable, the author proposes

adding some means to continuously vary the energy supplied to the plant by the relay controller. It is to this latter point that Dr. Nelson devotes a considerable portion of his paper, including derivations, test results, and a practical circuit of a pulse width controller and relay.

Basically, the pulse-width control function creates a dual mode operation: for large errors the corrective "on" pulse width equals the full duration of the sampling half-period T, and for smaller errors the pulse-width τ is a continuously varying factor less than T as determined by the magnitude and polarity of the input and by a scale factor β. Thus τ is a function of the full energy input MT, where M is input pulse amplitude.

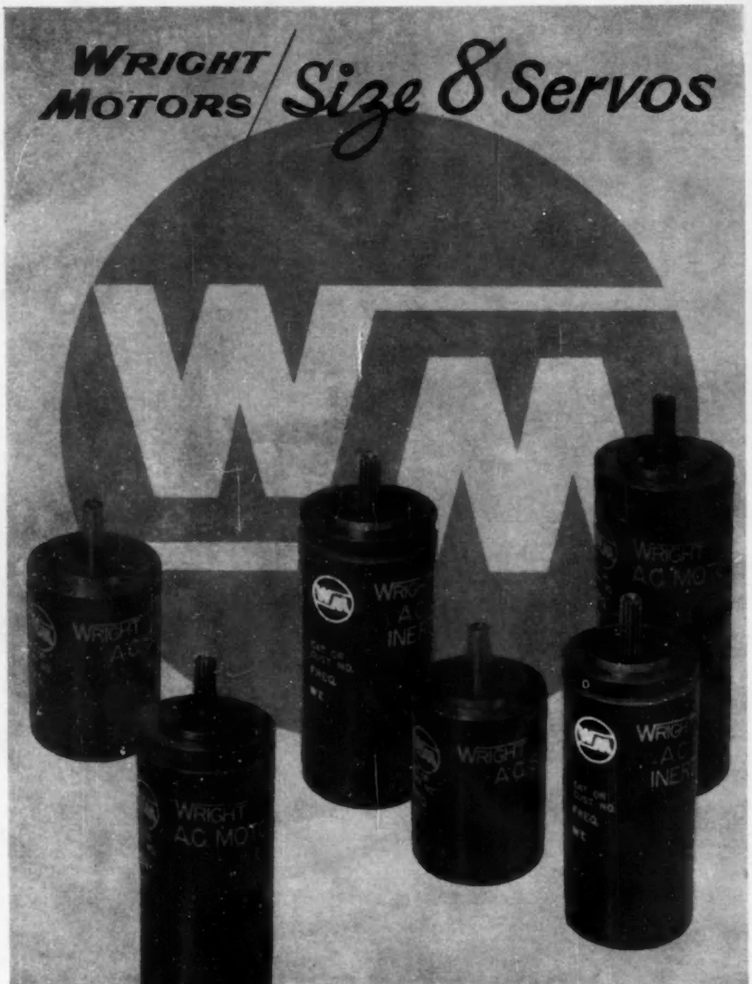
Even without any sampled-data plant input the excursion of the output resulting from the limit cycle itself constitutes, due to closed-loop configuration of the control system, a (sampled) input error. To eliminate the output error it is necessary to eliminate the limit cycle. As three sets of state space trajectories and input and output waveforms show, one value of β will not eliminate the limit cycle, another will eliminate the limit cycle but suffer several cycles of overshoot before the output stabilizes, while a third, more judicious choice of β provides asymptotic stability.

Weighting instrument errors

From "Measurement Accuracy as a Weighting Factor in Statistical Treatment of Data", by D. M. Aspinwall and J. F. Rey, Lockheed Aircraft Corp. Paper 66-NY60 presented at the Instrument Society of America Fall Instrument-Automation Conference, New York, Sept. 26-30, 1960.

In the statistical analysis of experimental data, instrument errors assume greater importance as technology progresses and analysis techniques become refined. If measurement accuracy is expressed in probability terms, the theory presented in this paper can be used to counteract the errors by giving each measurement a different weight based on its accuracy.

A measurement instrument is needed to define physical properties of a sample taken from an unknown population. Population, in a statistical sense, means the collection of all values which have been or will be assumed by the given variable. Test measurements depend on values drawn from two populations: the population of the variable being measured and the population of instrument errors which are essentially caused by the



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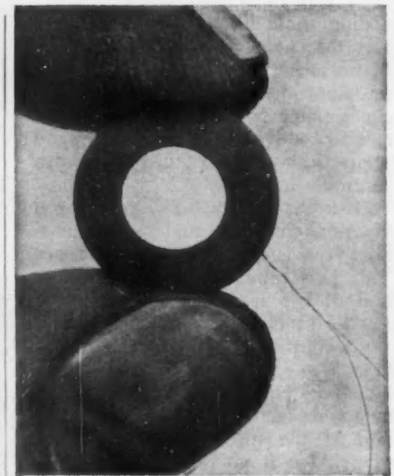

In the Remington Rand Univac physics laboratory, 5 mil. diameter holes are ultrasonically drilled in ferrite cores, then threaded with fine wire in the examination of domain structure. Such experiments prove that a series of alternate-polarity pulses of diminishing amplitude result in concentric rings of alternately directed magnetization. Much smaller cores (80 mil. o.d.) were then studied by means of residual magnetization curves for flux distribution under various modes of partial switching.

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lack of resolving power of the measurement instrument. The distorting effect of errors must be recognized by giving accurate measurements more authority in the computation of population mean and variance.

Russian analyzer

From "Reliable Concentration Meter with Linear Scale", by V. A. Gorbunov and I. I. Zaslavskii. Instrument Construction, December 1959, pp. 3-7. Translated from Russian by Taylor & Francis Ltd., London.

The usual method of determining the concentration of an electrolyte is to measure the electrolyte's electrical conductivity. The method employs a conductance cell whose electrodes intimately contact the liquid. Still other methods employ electrodes that do not contact the liquid. The Russian instrument described goes further: electrodes are eliminated altogether.

The instrument employs a transformer in which the secondary circuit is formed by a flow-through-sample electrolyte circuit. An induced emf in the electrolyte circuit generates an electrolytic current whose magnitude depends on the conductivity of the liquid, thus on concentration.

The electrolytic current is measured by the null method, using a differential transformer with the liquid circuit acting as one of the primaries. When the electrical conductivity of the solution changes, an error signal appears that drives a servosystem to null. A pointer coupled to the servomotor linearly relates rotor position to concentration.

Models of this instrument have been built to measure concentration of electrolytes with conductivities as high as 0.018 ohm-cm^{-1}. The instrument's transmitters can measure the concentration of skinforming and contaminated electrolytes to plus or minus 1.5 percent.

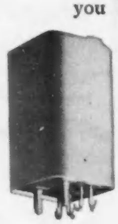
The translation contains a schematic of the analyzer and the details of its immersion-type transmitter. Also discussed are the influences of sample temperature on concentration indication and the method of automatically compensating the instrument for temperature changes. For instance, with compensation the error in a 0.1 per cent HCl solution remains within one percent over the range from 10 to 30 deg C.

if all you have for a relay is a sudden impulse...

An impulse relay—one that when pulsed will turn something on and leave it on and when identically pulsed again will turn the load off and leave it off—is nothing new. For years you've been able to buy them, complete with ratchets, pawls, escapements, walking beams, lock-in mechanisms, etc., in a regular commercial quality grade. Sequencing and stepping relays are the more educated relatives in the family.

But in the recent trend of getting more things up in the air, and generally getting more and more out of smaller and smaller relays for practically no power and under unpleasant conditions, the standard commercial impulse relay has often gotten dirty looks. Generally, it wouldn't hold together under the vibration or shock levels, and its size and relatively short life further complicated things.

Naturally, Sigma now has an impulse relay with none of the above drawbacks (mostly because it has none of the above mechanical mechanisms). SPDT contacts will switch 2 amp. resistive loads (28 VDC/120 VAC) 200,000 times; mechanical life with no contact load is 4 million operations. It works on positive DC pulses as short as 1 millisecond, at speeds up to 10 pps. For the space, weight and power pinchers, this new hermetically sealed relay takes up 1" x 1" x 1¾", weighs about 2¼ ounces and transfers its contacts on as little as 250 microjoules (e.g., 250 mw. for 1 ms.). Vibration immunity is in the order of 30 g's to 2000 cycles, operating temperature −65° to +125°C. About the only caution is that you've got to feed it pulses of the same polarity.



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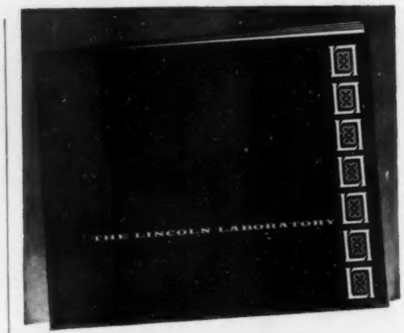

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NEW BOOKS

Analog Computer Guide

Analog Computation in Engineering Design, A. E. Rogers and T. W. Connolly. 450 pp. Published by McGraw-Hill Book Co., Inc. $16.

This newest addition to the McGraw-Hill Series in Information Processing and Computers is written at an academic level higher than most other books on this subject. Less like a cookbook and more like a textbook, this book is strong on mathematics and theory. Still it presents all the necessary computer techniques for simulating a wide variety of engineering problems and does so in a clear and comprehensive manner.

After a brief introductory chapter the authors devote 40 pages to descriptions of typical analog computer components. They follow up this basic material with a comprehensive discussion of the linear analysis of dynamic systems. Both ordinary and partial linear differential equations with constant coefficients are analyzed at great length. An excellent section on degrees of freedom and constraints is one of the highlights of the theoretical treatment found in this chapter. The use of analog computer models for system simulation is discussed in the latter sections of the chapter; the concluding section shows how to simulate systems described by ordinary linear differential equations with varying coefficients.

As good as this chapter is, only a slight increase in the number of pages could have made it even better. First, explicit statements of both Lagrange's and Hamilton's equations of motion, instead of mere descriptions of the equations, could have rounded out the discussion of methods of system analysis. Second, it was unfair of the authors to refer the reader to another book for tabulations of complex networks that are used in simulating complicated transfer functions with an operational amplifier. The authors did a good job of tabulating numerous circuits for simulating nonlinear phenomena; it is regrettable that they did not supplement them with a like number of circuits for linear systems.

A brief but adequate chapter on nonlinear differential equations comes next. This is followed by a fairly extensive introduction to partial differential equations, with the emphasis naturally placed on those equations arising from simple physical systems. Methods of mathematical solution are

quite fully explained and lay the groundwork for the analog computer methods of solution that are discussed next. The authors are very thorough in their treatment, paying particular attention to approximation errors and ways of reducing them.

The next chapter represents, to the reviewer's knowledge, the first time that a book has contained a detailed description of methods for solving algebraic equations on an analog computer. Linear and nonlinear algebraic equations, eigenvalue problems, steepest ascent problems, and linear and nonlinear programming problems are all covered in this excellent chapter.

Two chapters on random signals and their use in analog computing appear next. A technique for programming noise on an analog computer is explained; it is then used to obtain the rms response of a simulated linear system. The second of these two deals with a special technique for obtaining the response of a linear, time-varying system to noise inputs. This technique, known as adjoint computation, is much simpler and faster than any other in use today; its inclusion in the book is highly commendable.

Solution of specialized problems is very briefly covered in the next chapter; this is followed by a very detailed discussion on preparation of problems for the analog computer. The remaining six chapters are devoted to applications of analog computers in various special fields.

There has never been another analog computer book that has delved as deeply into the mathematical background but still presented enough practical information for the inexperienced to set up their own simulation problems. It is heartily recommended.

Leslie R. Axelrod
The Powers Regulator Co.

Writer's Aid

TECHNICAL WRITING TECHNIQUES FOR ENGINEERS, *Joseph Racker. 234 pp. Published by Prentice-Hall, Inc., Englewood Cliffs, N. J.* $6.95.

Another in a host of guidebooks, manuals, and textbooks aimed at making the engineer into a passable writer, this new volume is concerned not so much with proper English in technical writing as with forms and techniques. Author Racker suggests methods for choosing the proper words and includes a 106-page glossary of technical terms.

MEETINGS

FEBRUARY

Institute of Radio Engineers, Second Winter Military-Electronics Convention, Biltmore Hotel, Los Angeles, Calif. Feb. 1-3

Eighth Annual International Solid-State Circuits Conference, sponsored by IRE, AIEE, and University of Pennsylvania, University of Pennsylvania Campus and Sheraton Hotel, Philadelphia, Pa. Feb. 15-17

Petrochemical and Refining Exposition, 44th National AIChE Meeting, Roosevelt Hotel, New Orleans, La. Feb. 26-March 1

MARCH

Instrument Society of America, 11th Annual Spring Conference on Instrumentation for the Iron and Steel Industry, Roosevelt Hotel, Pittsburgh, Pa. March 8-9

American Institute of Electrical Engineers, Second Symposium on Engineering Aspects of Magnetohydrodynamics, University of Pennsylvania, Philadelphia, Pa. March 9-10

Institute of Radio Engineers, International Convention, Coliseum and Waldorf Astoria Hotel, New York, N. Y. March 20-23

Temperature—Its Measurement and Control in Science and Industry (Third National Symposium), sponsored by American Institute of Physics, ISA, and National Bureau of Standards, Columbus, Ohio March 27-31

APRIL

Institute of Radio Engineers, 13th Annual Southwest IRE Conference and Electronic Show (SWIRECO), Dallas Memorial Coliseum, Dallas, Tex. April 19-21

Institute of Radio Engineers, Seventh Region Technical Conference and Trade Show, Westward Ho Hotel, Phoenix, Ariz. April 26-28

MAY

National Aeronautical Electronics Conference (NAECON) Institute of Radio Engineers, Miami and Dayton Biltmore Hotels, Dayton, Ohio May 8-10

Western Joint Computer Conference, sponsored by IRE, AIEE, ACM, Ambassador Hotel, Los Angeles, Calif. May 9-11

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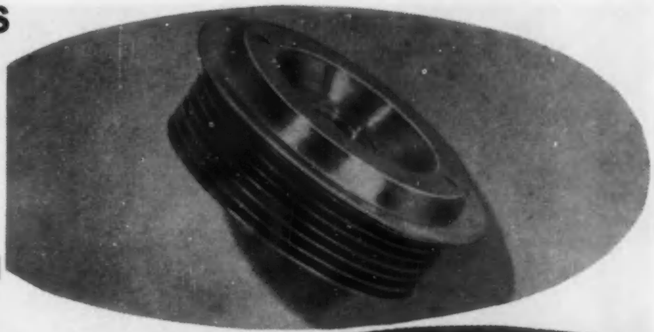
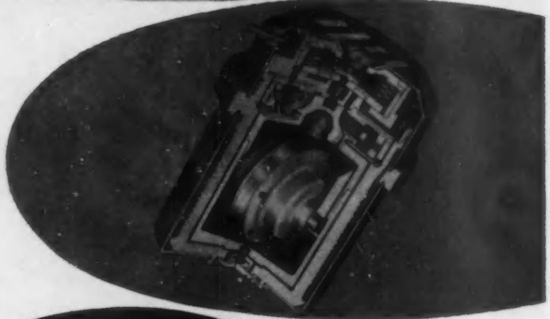


Selected by Minneapolis-Honeywell For New Gas-Bearing Gyroscope



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WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 163. Don't send money with card, we will bill you later. For multiple copies write Reader Service Dept. Quantity rates will be quoted on request.

507—Tips on the Use of Electromechanical Relays, 24 p. Compilation of five articles presents practical information on the design, test, and use of relay control systems. Topics covered include: testing relay electrical reliability, improving system reliability, narrowing relay differential, logical synthesis of systems, and verifying relay control circuits. 65 cents.

506—What You Should Know About Adaptive Systems, 17 pp. Is there such a thing as an adaptive control system? What approaches have been taken? What does the future hold? These are the questions the author answers in this three-article reprint, in sufficient detail and with sufficient references to provide a basic grounding in this latest area of control engineer interest. 50 cents.

505—The Basics of Optimum Response Relay Servos, 17 pp. Three part series summarizes all of the important design techniques that have been used to optimize the response of relay servos. The reprint describes the development of the optimum switching criteria, and outlines the progress that has been made in implementing this theory with hardware for second-order and higher-order systems. Extensive references provide a guide for further study. 50 cents.

504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

503—How to Determine Stream Analyzer Dynamics, 8 pp. This package of two articles shows how analyzers can introduce dynamic errors, how to determine analyzer dynamics, and how to improve performance. The instrument used is a differential refractometer but techniques can be extrapolated to other types of analyzers. 40 cents.

(Continued on page 196)

REPRINTS cont'd

502—Survey of Dynamic Display Techniques, 20 pp. The function of these newly developed techniques is to put up-to-date information in the hands of human operators of control systems when the information changes at a high rate. Both basic approaches and commercial hardware are discussed for cathode ray tube displays, optical systems, and miscellaneous devices ranging from TV pickup to matrix cells. 50 cents.

501—Six Transducers for Precision Position Measurement, May 1960, 6 pp. Explains operation and gives practical application hints for six precision position transducers: pin-and-pawl mechanism, magnetic bench-mark system, resolver-type transducer, electrostatic transducer, coded-disc devices, and diffraction gratings. 30 cents.

500—Ready Reference Data Files—I, II, III, 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in CONTROL ENGINEERING through **April 1960. The** 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. $1.35.

499—Ready Reference Data Files—III, 28 pp. Includes the third dozen Data Files published in CONTROL ENGINEERING. Topics range from control of metal properties with eddy currents to electrically signaled valve actuators to stabilization of sampled data systems. 60 cents.

498—Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in CONTROL ENGINEERING. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

497—Ready Reference Data Files—I, 24 pp. A must for every control engineer's library. Includes the first 12 data files published in CONTROL ENGINEERING—a diversity of topics from system reliability through the cost of industrial temperature-measuring systems. Each one gives a method of solving a particular problem. 50 cents.

496—How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

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(Continued on page 198)

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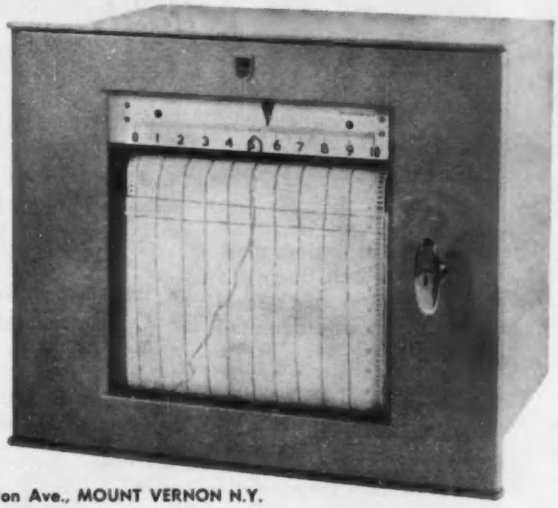

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492 – Analysis Instrumentation – III – Electrochemical Methods, Mass Spectrometry, Continuous Viscometers, X-Ray Techniques, K-Capture, Physical and Chemical Property Testers, Emission Spectroscopy, 48 pp. Reprint includes last nine articles of Analysis Instrumentation Series. 90 cents.

491–Analysis Instrumentation–II–Refractometers, Infrared Analyzers, Ultraviolet Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

489–Fundamentals of Multivibrators, 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds. They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This reprint covers a broad selection of multivibrator circuits. 45 cents.

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487–Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Regarded as constant speed devices, multispeed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

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(*Continued on page 201*)

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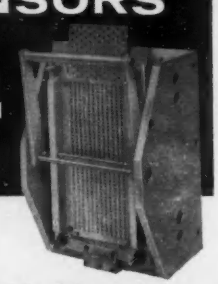

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483—Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

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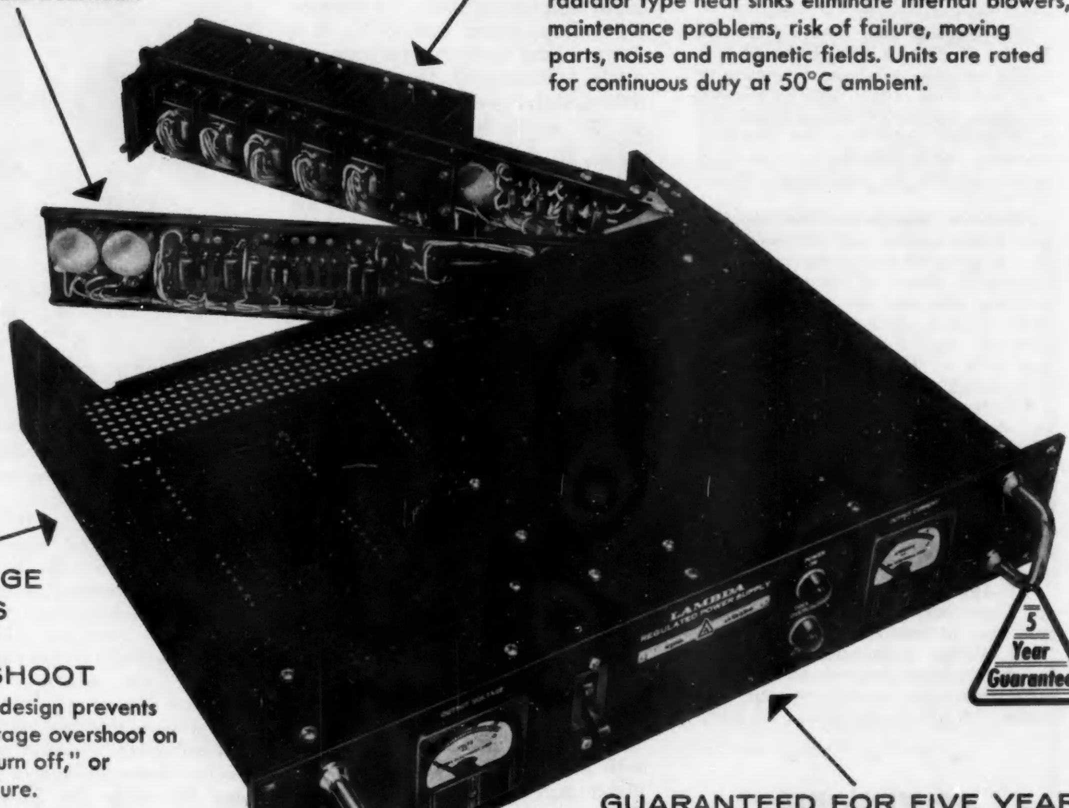

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Model	Voltage Range[1]	Current Range[2]	Price
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LA 50-03AM	0-34 VDC	0- 5A	$425
LA100-03A	0-34 VDC	0-10A	$510
LA100-03AM	0-34 VDC	0-10A	$540
LA200-03A	0-34 VDC	0-20A	$795
LA200-03AM	0-34 VDC	0-20A	$825

[1]The output voltage for each model is completely covered in four steps by selector switches plus vernier control and is obtained by summation of voltage steps and continuously variable DC vernier as follows:

MODEL	VOLTAGE STEPS
LA 50-03A, LA 50-03AM	2, 4, 8, 16 and 0-4 volt venier
LA100-03A, LA100-03AM	2, 4, 8, 16 and 0-4 volt venier
LA200-03A, LA200-03AM	2, 4, 8, 16 and 0-4 volt venier

[2]Current rating applies over entire output voltage range

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LA100-03A less than .004 ohms
LA200-03A less than .002 ohms

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LA100-03A ...680 watts[4]
LA200-03A...1225 watts[4]

[3]this frequency band amply covers standard commercial power lines in the United States and Canada.
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	LA100-03A	100 lb Net	130 lb Ship. Wt.	
	LA200-03A	140 lb Net	170 lb Ship. Wt.	

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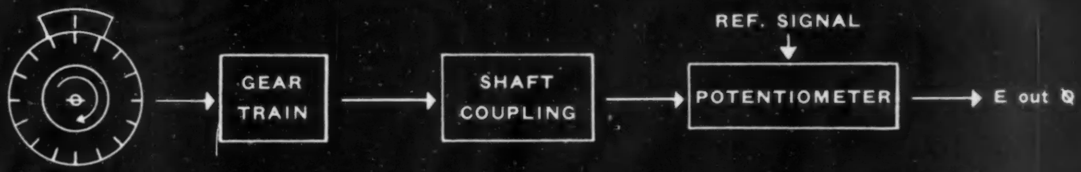

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